Lawrence Livermore National Laboratory

Annual Report 2003

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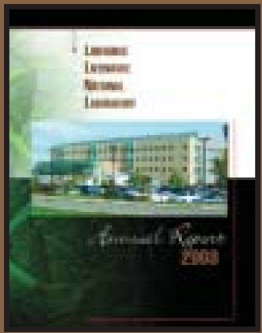
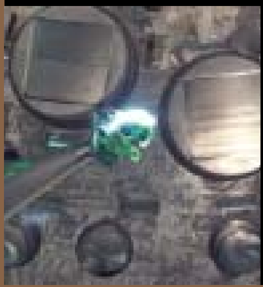
About the Cover

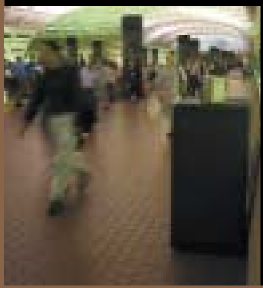


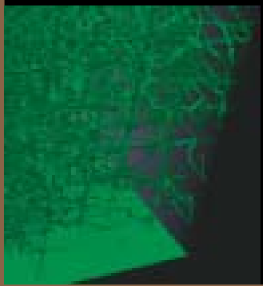
Beginning in 2005, the Terascale Simulation Facility will house new supercomputers called Purple and BlueGene/L. Purple, the world's most powerful production computer, will enable 3D simulations of the performance of a full nuclear weapon system. BlueGene/L, based on an entirely different technology, called "system-on-a-chip," will be used to explore the properties of materials at all scales.

About the Laboratory

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons research facility. The Laboratory has been managed since its inception by the University of California, first for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and establish an atmosphere of intellectual integrity and innovation, both of which are essential to sustained scientific and technical excellence. As an NNSA national laboratory with about 8,000 employees, Livermore has an essential and compelling core mission in national security and the scientific and technical capabilities to solve nationally important problems.







A Message from the Director

Michael R. Anastasio

Outstanding achievements in 2003 contributed to a successful year for Lawrence Livermore National Laboratory. From the first experiments on the National Ignition Facility and the JASPER gas gun to new biological agent sensor systems and radiation detectors, the Laboratory's science and technology are strengthening national and homeland security. Major advances in supercomputing are improving our abilities to sustain a safe and effective nuclear deterrent while they are creating wide-ranging opportunities for scientific discovery.

As part of the Department of Energy's National Nuclear Security Administration (NNSA), national security is the Laboratory's primary mission. Stewardship of the nation's nuclear weapons stockpile is our foremost responsibility, and we strongly contribute to national efforts to prevent the proliferation of weapons of mass destruction and provide homeland security. With Livermore's unique research and development capabilities and our multidisciplinary approach to problem solving, Laboratory scientists and engineers are also delivering innovative products to meet important national needs in energy and environment, biosciences, and basic sciences.

Our exciting future is evident in this annual report, which highlights many of our significant accomplishments in 2003 and the direction of major research programs at Livermore. Our scientific and technological breakthroughs are meeting the important mission objectives of NNSA and other government sponsors. The report also describes our efforts to continually improve Laboratory operations and the excellent results achieved in recent external reviews of security and business practices. It is vitally important that Laboratory operations continue to be carried out in an efficient, safe, secure, and environmentally responsible manner.

An outstanding workforce is the key to our successes. Exceptional people make Livermore an exceptional national laboratory. With our commitment to national service and excellence in all our activities, we are excited to take on the opportunities and challenges the future offers. The Laboratory has much to accomplish as we work to make the world more secure and a better place to live.

"Edward Teller helped shape the course of human history."

—President George W. Bush,
on presenting the Presidential Medal of Freedom

"He was a major part of the flowering of American science. Edward Teller didn't just make a difference, he made a gigantic difference."

—George Shultz, former Secretary of State

Dr. Edward Teller

An Extraordinary Life

Edward Teller, renowned physicist and Director Emeritus and co-founder of Lawrence Livermore National Laboratory, died at his home on the Stanford University campus on September 9. He was 95.

Teller memorial service at Livermore.

Less than two months earlier, President George W. Bush honored Teller with the Presidential Medal of Freedom, the nation's highest civilian honor. Teller was too ill to attend the ceremony, but his daughter, Wendy, accepted the medal on his behalf. Teller received many honors over the years, but he was especially touched by this one. He said, "In my long life, I had to face some difficult decisions and found myself often in doubt whether I acted in the right way. Thus, receiving the medal is a great blessing for me."

A memorial service was held at the Laboratory on November 3 where friends, colleagues, congressional representatives, and family paid tribute to the many dimensions of Teller's life. He was celebrated as a man of science, teacher, patriot, adviser to presidents, family man, musician, and poet.

"To me, Edward Teller will always be my dad. My father went to work five days before he died. Many people say this is an indication of his dedication and determination. I see this as an indication of his dedication to his friends and colleagues. The fact that his friends made it possible for him to work until his last days was a source of joy to him. Your friendship was the cornerstone of my father's success and his happiness."

—Wendy Teller, daughter of Edward Teller

Daughter Wendy and son Paul at the memorial service.

Target alignment positioner in the National Ignition Facility's target chamber.

Laser glass for the National Ignition Facility.

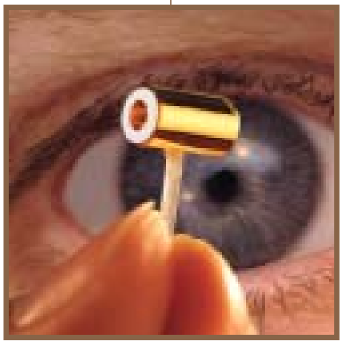
Nuclear Weapons
Stockpile Stewardship

Lawrence Livermore National Laboratory was established in 1952 to help ensure national security through the design, development, and stewardship of nuclear weapons. National security continues to be the Laboratory's defining responsibility. Livermore is one of the three national security laboratories that support the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE).

Livermore plays a prominent role in NNSA's demanding Stockpile Stewardship Program for maintaining the safety and reliability of the nation's nuclear weapons. The Stockpile Stewardship Program integrates the activities of the U.S. nuclear weapons complex, which includes Livermore, Los Alamos, and Sandia national laboratories as well as four production sites and the Nevada Test Site. As the nuclear weapons in the stockpile continue to age, Laboratory scientists and engineers must ensure their performance and refurbish them as necessary without conducting nuclear tests.

Working with the other NNSA laboratories, Livermore is attending to the immediate needs of the stockpile through assessments and actions based on a combination of laboratory experiments and computer simulations of nuclear weapon performance. In addition, the Laboratory is acquiring more powerful experimental and computational tools to address the challenging issues that will arise as the nation's nuclear weapons stockpile continues to age. These vastly improved scientific capabilities will also be used by experienced nuclear weapons designers to train and evaluate the skills of the next generation of stockpile stewards.

Rapid-growth, large crystal for National Ignition Facility optics.



Capsule that holds a National Ignition Facility fusion target.

Ambassador Linton Brooks, administrator of the National Nuclear Security Administration, at the Laboratory.

Certifying Stockpile Safety and Reliability

Livermore is a key participant in formal review processes and assessments of weapons safety, security, and reliability. In 2003, the eighth cycle of the Annual Assessment Review was completed. This annual certification of the stockpile was first mandated by the president and is now required by law as a result of congressional legislation enacted in 2002. The formal process is based on the technical evaluations made by the laboratories and on advice from the three laboratory directors, the commander-in-chief of Strategic Command, and the Nuclear Weapons Council. To prepare for this process, Livermore scientists and engineers collect, review, and integrate all available information about each stockpile weapons system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review, including formal use of red teams.

For the Annual Assessment Review—and the formal certification of refurbished warheads—weapons experts depend on an extensive range of aboveground testing, vastly improved simulation capabilities, and the existing nuclear test database. Livermore and Los Alamos have developed and are implementing a new methodology, quantification of margins and uncertainties (QMU), that is serving as the basis for formal certification actions. Important decisions at the Laboratory about research and development priorities in support of the Stockpile Stewardship Program are also guided by QMU considerations. The methodology, which entails the development and application of a rigorous set of quantitative standards, is analogous to the use of engineering safety factors in designing and building a bridge. The QMU approach was first applied in Livermore's certification of the design changes to refurbish and extend the life of the W87 ICBM warhead.

Life Extension of the W87 ICBM Warhead and the W80 Cruise Missile Warhead

Livermore's W87 Life Extension Program, begun in late 1994, continues to meet all its major milestones. The program has been a very successful demonstration of stockpile stewardship in the absence of nuclear testing. Refurbishment of the W87 ICBM warhead, the design with the most modern safety features in the stockpile, extends the lifetime of the weapon to beyond 2025. The Laboratory developed and certified the engineering design of the W87 modification through a combination of nonnuclear experiments, flight tests, physics and engineering analyses, and computer simulations.

Refurbished W87 warheads are being delivered to the Air Force after assembly at the Pantex Plant in Texas. The Laboratory is collaborating with the production plants, working to ensure the quality of the W87 refurbishment work while maintaining the targeted production rate. The final unit is scheduled for completion in 2004.

Lawrence Livermore and Sandia national laboratories have also assumed responsibility for the W80 Life Extension Program. In October 2004, the two laboratories will assume responsibility for all currently stockpiled W80 warheads as well. The W80, designed by Los Alamos, is currently deployed in air-launched and sea-launched cruise missiles. An extensive program of experimental and computational activities was performed in 2003 in support of a life extension schedule that calls for completing the first production unit of the refurbished warheads in FY 2008.

Laboratory scientists performed numerous high-resolution, 2D and 3D computer simulations to design and test new components, predict system performance, and prepare for certification of the W80's proposed modifications. The simulations also assisted in the preparation of experiments, and the tests, in turn, provided data to compare with model predictions.

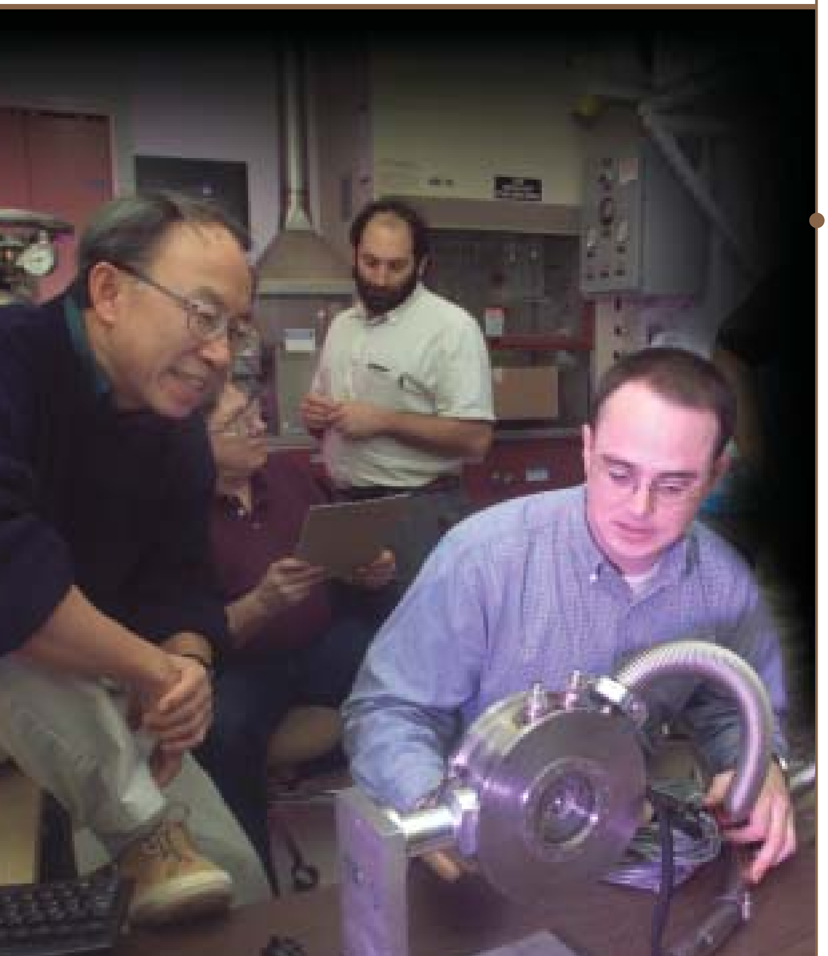
A particularly important part of the W80 Life Extension Program is hydrodynamic testing, in which scientists study the performance of mock weapon primary pits as they are imploded by high explosives. Hydrodynamic experiments are carried out in the Contained Firing Facility at Site 300, the Laboratory's experimental test area 24 kilometers southeast of the main site. The facility's firing chamber is designed to contain the blast (up to 60 kilograms of high explosive) and minimize the environmental consequences in repetitive tests. Hydrodynamic tests performed in 2003 for the W80 program showed impressive agreement with the predictions provided by computer simulations.

W80 test unit.

Inside the Contained Firing Facility.

Experiments to Better Understand Plutonium

A research team led by Livermore scientists conducted landmark experiments that promise to reveal much about the physics and material properties of plutonium. Plutonium is an extremely complex material, and it is critically important to the functioning of



Plutonium phonon research team.

JASPER gas gun.

nuclear weapons. Comprehending the detailed properties of plutonium metal and alloys is one of the major scientific challenges in the Stockpile Stewardship Program. As the plutonium in deployed weapons grows older, the effect of aging-related changes on weapon performance must be thoroughly understood.

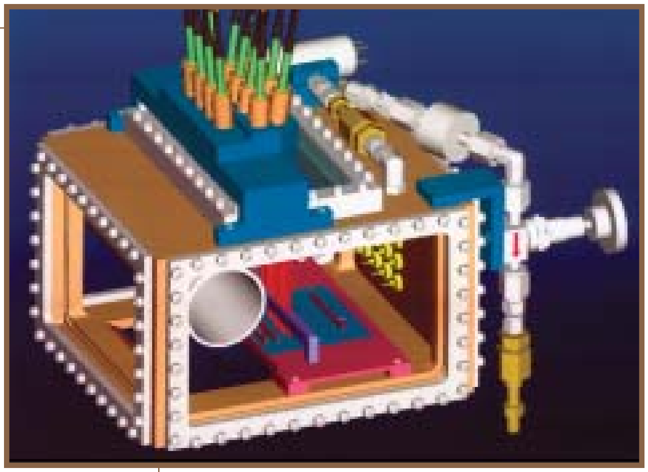
As reported in *Science*, the research team fully mapped the phonons in an alloy of plutonium—gallium-stabilized delta plutonium—for the first time. Phonons are lattice vibrations produced by the movement of atoms in a solid. Their variations along different directions in a crystal, called phonon dispersion curves, describe how atoms move within a solid. These data are key to understanding many of plutonium's physical and structural properties.

Plutonium and its alloys have defied phonon measurements for the past 40 years, in part because the conventional method for mapping the data requires the growth of large single crystals. Instead, the team was able to obtain the data by focusing a micro-beam from an extremely bright x-ray synchrotron source on a single grain of plutonium alloy. The work was performed at the European Synchrotron Radiation Facility in Grenoble, France. Researchers at that facility and the University of Illinois at Champaign-Urbana were part of the team.

Livermore scientists are also investigating the properties of plutonium at extreme conditions—high temperatures, pressures, and strain rates. In July 2003, the first experiment with a plutonium target was conducted at the Joint Actinide Shock Physics Experimental Research (JASPER) Facility at the Nevada Test Site. Livermore took the lead for NNSA in constructing JASPER and bringing it into operation. This multi-laboratory user facility is designed to accommodate experiments to study uranium, plutonium, and other hazardous materials.

JASPER is a nearly 30-meter-long, two-stage gas gun that accelerates a projectile to speeds of up to 8 kilometers per second. The impact of the projectile produces an extremely high pressure shock wave in the targeted material. High-speed diagnostics gathered precise data about the equation-of-state of shocked plutonium in the first experiment, which used a tantalum projectile fired at 5 kilometers per second. Three tests were completed in 2003, and about 24 tests per year are planned for the future.

These gas-gun experiments are augmented by high-static-pressure (diamond-anvil) experiments at the new high-pressure beam line at Argonne National Laboratory's Advanced Photon Source as well as subcritical tests conducted in an underground tunnel at the Nevada Test Site. Diamond-anvil cell experiments supplied information about the crystal structure of the high-pressure phase of plutonium and led to the discovery of a new phase of this element. The highly instrumented subcritical tests provide data on the behavior of plutonium when it is strongly shocked with explosives and show how that behavior depends on the plutonium's age. In September 2003, the Laboratory conducted a highly successful subcritical experiment named Piano.



Simulation of experimental setup for the Piano test.

From Construction Project to Experimental Facility

Major progress continues to be made on construction of the National Ignition Facility (NIF). Upon completion in 2008, NIF's 192-beam ultraviolet laser system will be used to compress fusion targets to conditions required for thermonuclear burn, liberating more energy than that required to initiate the fusion reactions. Other NIF experiments will study physical processes at temperatures approaching 100 million degrees and 10 billion atmospheres, conditions that exist naturally only in the interior of stars and planets and in exploding nuclear weapons. These temperatures and pressures are needed to validate weapons-physics computer codes and address important issues of stockpile stewardship. Experiments on NIF will also evaluate the feasibility of inertial fusion energy, a long-standing program goal within DOE. In addition, NIF will allow laboratory studies of astrophysics and materials under conditions similar to those found in stars.

Laser beams travel to the target chamber through these enclosures in one of the National Ignition Facility's two laser bays.

The project continues to meet its cost and schedule milestones. With the September 2003 completion of installation of beam-path infrastructure for all 192 laser beams, the NIF laser system is ready for the installation of the hundreds of precision optical and opto-mechanical assemblies—called line replaceable units (LRUs)—that make up each laser beam. Altogether more than 7,500 large precision optics and more than 26,000 small optical components are being assembled into the LRUs and installed in each beam line. Laboratory scientists and engineers are working in partnership with the optics industry to implement production processes for manufacturing NIF's precision optics.

National Ignition Facility.

A key event for the transformation of NIF from a construction project to an experimental facility was activation of the first four laser beams, called a quad, in December 2002. This goal—NIF Early Light—was established in 2001 to provide early demonstration that the integrated laser system works and to

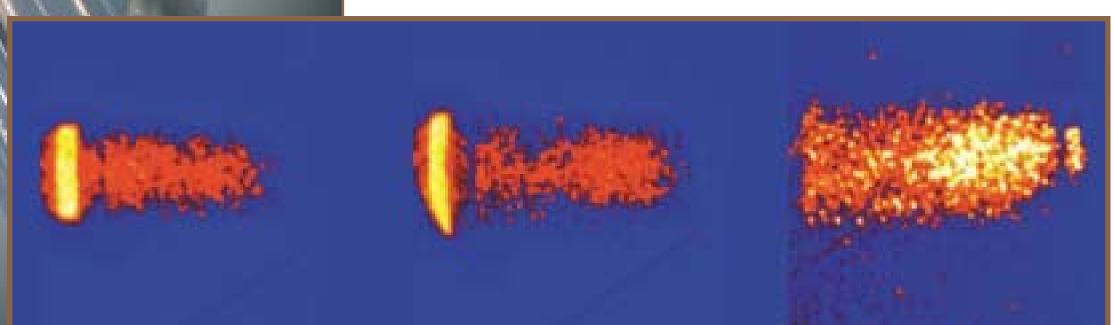
Wedged focus lens for National Ignition Facility.

expedite the start of NIF's experimental program. In May 2003, 10.4 kilojoules (kJ) of ultraviolet light were produced in a single laser beam line, setting a world record for laser performance. In subsequent shots, NIF set single-beam-line energy records for infrared and green light (26 kJ and 11 kJ, respectively). With just 4 of its 192 beams in operation, NIF is already the highest energy infrared laser in the world.

Laser beam quality on NIF meets performance criteria for beam energy, beam output, uniformity, beam-to-beam timing, and delivery of shaped pulses. Overall, the NIF laser system has demonstrated ultraviolet laser energy equivalent to 2 million joules (MJ) in all 192 beams, which exceeds the specified design requirement of 1.8 MJ. In addition, the functioning of the first laser quad successfully tested almost all of the critical systems in NIF including laser components and optics, the laser beam path and supporting utilities, the power conditioning system, diagnostics, and computer controls.

After achieving Early Light and demonstrating key aspects of NIF's laser performance, the project team transported the beams to the final optics mounted on NIF's 10-meter-diameter target chamber. The final optics convert the infrared laser light to ultraviolet light and focus it precisely to the center of the chamber, which is kept under vacuum. Laser performance and physics experimental campaigns are now regularly conducted using the first diagnostics mounted on the target chamber. By the end of 2003, more than 200 full-system shots had been fired.

In August 2003, scientists performed the first set of physics experiments at NIF. Ultraviolet light from NIF's first quad of lasers was precisely aimed at millimeter-sized, gas-filled targets in the center of the target chamber. The experiments were fielded to study the interaction of intense laser beams with low-atomic-number



Laser–plasma interaction experiment at the National Ignition Facility. The target used is at the left.

Inside the National Ignition Facility target chamber (photo courtesy of *National Geographic*).

gases such as carbon dioxide. The first of NIF's sophisticated experimental diagnostics were used to measure the x rays produced. Preliminary results were presented at the Third International Conference on Inertial Fusion Sciences and Applications, in Monterey, California, in September. The conference was hosted by the University of California and Livermore.

Advances in High-Energy-Density Physics and Future NIF Experiments

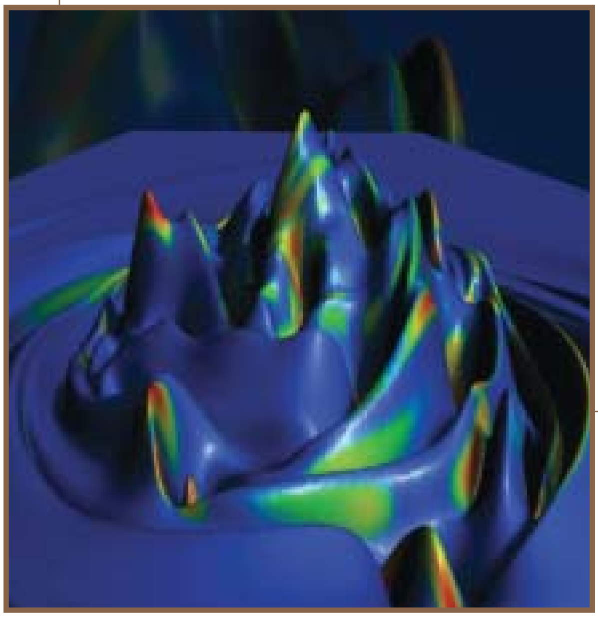
Laboratory scientists are making significant advances in high-energy-density physics through computer simulations and experimental research at a number of laser and pulsed-power facilities in the U.S. and around the world. Their work is leading to imaginative ways to use the NIF facility more effectively—beyond what was conceived when the NIF project began. Many exciting proposals are emerging for high-energy-density physics experiments, and researchers are exploring ways to make NIF an even more capable facility. For example, shorter pulses on NIF, using special optical systems to generate picosecond pulses, can provide an enhanced x-radiography capability, which is important for diagnosing high-density and high-atomic-number experiments on NIF.

Livermore scientists are performing groundbreaking research using short-pulse, high-power lasers. In 2003, the JanUSP laser at Livermore was used to create a focused beam of high-energy protons that could rapidly heat targets for equation-of-state experiments. Configuring some NIF beam lines to function as ultra-short-pulse lasers would make such experiments possible as well as high-energy (10-kiloelectronvolt to 1-megaelectronvolt) x-radiography and high-energy (50-megaelectronvolt) proton radiography. These capabilities would allow experimentalists to study much denser and higher atomic number targets with NIF.

Computational modeling of ignition in laser fusion capsules has led researchers to suggest operating NIF's lasers in multiple colors (green and ultraviolet) instead of just one color (ultraviolet). This option would allow even higher energies to be directed onto targets, which could be advantageous for higher gain fusion yields and for stockpile stewardship experiments on materials. In 2003, a Laboratory researcher who performed studies on optimizing NIF ignition targets at green and ultraviolet wavelengths was awarded a prestigious Edward Teller Medal for his work (see p. 44).

A power wall visualization of a 3D simulation.

ViSUS view of vortical flow simulation.



Improved Algorithms for and Visualization of 3D Simulations

The 3D physics simulations that Livermore scientists run in support of the Stockpile Stewardship Program require supercomputers performing in the range of teraops (trillions of operations per second). These computers are acquired through the Advanced Simulation and Computing (ASC) Program, previously known as the Accelerated Strategic Computing Initiative, or ASCI. ASC is the NNSA's vehicle for advancing scientific supercomputing so scientists can make much more realistic physics and engineering simulations of the performance of an aging nuclear weapons stockpile. At 12 teraops, ASCI White is the Laboratory's largest classified machine supporting stockpile stewardship, and greater capabilities are coming soon.

More than requiring just large machines, better simulations also depend on the development of computer algorithms that run efficiently on massively parallel computers. Sophisticated data management tools are essential for preparing problems and analyzing the enormous amount of information generated.

The Scalable Linear Solvers (SLS) project at Livermore is developing fast, parallel, multigrid algorithms and software for solving large, sparse linear systems of equations. This work, supported by both the ASC Program and the DOE Office of Science's Mathematical, Information, and Computational Sciences Program, is dramatically improving the capabilities of codes. The objective is to make simulations run faster and at much higher resolution. For example, new algorithms made possible the largest-ever ALE3D calculations in 2003. Used for large 3D structural dynamics simulations, ALE3D solved for 610 million unknowns, using 4,032 processors of the ASCI White supercomputer. This calculation is 100 times larger than the simulations of only three years ago, using just 10 times the number of processors.

To interpret the results of simulations, scientists turn to such software tools as Visualization Streams for Ultimate Scalability (ViSUS), developed at the Laboratory. ViSUS gives researchers full control over visualization parameters so they can explore and interact with their data in ways that are most useful to them. ViSUS supported a study of the mixing of two dissimilar liquids and led to the production of an award-winning video, "Visualizations of the Dynamics of a Vortical Flow," which can be viewed at www.llnl.gov/icc/sdd/img/images/aps02.mov.

The World's Most Powerful Computers

Construction of the $91-million Terascale Simulation Facility (TSF) will be completed in October 2004, on budget and over a year ahead of schedule. The TSF, an ASC facility, encompasses 253,000 square feet, including 48,000 square feet of raised computer floor. The facility also includes visualization theaters and laboratories to study the extremely large data sets produced by ASC scientists. The building will house more than 250 staff, primarily in secure work areas. Computer center staff expect to move into the building in November 2004. Two new computers, Purple and BlueGene/L, will be delivered the following year.

Purple is designed and built by International Business Machines (IBM) Corporation. This machine will be the world's most powerful production computer operating at 100 teraops. ASC Purple will enable 3D simulations with high-fidelity physics models of the performance of a full nuclear weapon system. It will help to meet critical stockpile stewardship deliverables—in particular, for life extension programs. The supercomputer will be powered by 12,288 microprocessors in 1,536 individual nodes, each node consisting of eight processors interconnected via two high-performance Federation switches. The system will also have 50 terabytes (trillion bytes) of memory, over 2 petabytes (quadrillion bytes) of disk storage, and 122 gigabytes per second of delivered input/output bandwidth. This machine is currently planned to run critical benchmarks at IBM in June 2005 and will be delivered in July 2005.

BlueGene/L will be delivered in stages during the first half of 2005. This IBM research computer is an innovative, scalable supercomputer based on low-power-consuming, "system-on-a-chip" technology. With 65,536 nodes, BlueGene/L will have a peak performance of 180 to 360 teraops. This machine will draw significantly less power than Purple (2 MW versus 7.5 MW) even though its peak speed is far higher. BlueGene/L will be used to explore properties of materials from atomic to engineering scales. Such work is expected to increase understanding of weapons physics and accelerate the development of better models of materials in weapons. These models would subsequently be incorporated into and improve the ASC weapons simulation codes that are run on production machines such as Purple. In addition, experience gained working with BlueGene/L could define a path to affordable petaops (quadrillion ops) computing in the 2007 to 2009 timeframe.

Terascale Simulation Facility.

Enrico Fermi Award for Seymour Sack

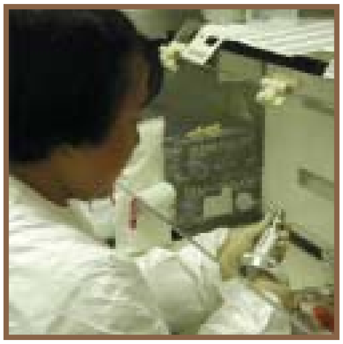
Seymour Sack, a Livermore physicist, earned an Enrico Fermi Award in 2003 "for his contributions to the national security of the United States." During his 35 years at the Laboratory, Sack emerged as one of the foremost U.S. nuclear weapons designers. His weapon-design programs introduced insensitive high explosives, fire-resistant plutonium pits, and other state-of-the-art nuclear safety elements into the nuclear weapons stockpile. Concepts developed by Sack are found in all U.S. nuclear weapons—designs from both Livermore and Los Alamos. The Fermi Award was presented by DOE Secretary Spencer Abraham on behalf of President Bush. It recognizes scientists of international stature for lifetimes of exceptional achievement in the development, use, or production of energy.

Autonomous Pathogen Detector System (right foreground) deployed in a Washington, D.C., Metro station.

Samples from biosensors.

Reducing the Threat from *Weapons of Mass Destruction*

The collapse of the Soviet Union more than 10 years ago created a grave threat of proliferation, with hundreds of weapons and thousands of pounds of weapons-usable materials potentially at risk for theft or diversion. The terrorist attacks in New York and Washington, D.C., in September 2001 transformed the possibility of terrorism against this country into reality. All during this time, Lawrence Livermore has been deeply involved in activities aimed at reducing the threats posed by the proliferation of nuclear weapons and other weapons of mass destruction (WMD) to rogue nations or terrorist groups.



Analyzing samples from biosensors.

The Laboratory draws on 50 years of experience in all aspects of nuclear weapons to address the challenge of nuclear nonproliferation. It leverages its extensive resources in biology, chemistry, engineering, and computations to tackle the problem of chemical and biological weapons proliferation. Laboratory researchers work closely with the intelligence, law enforcement, emergency response, and public health communities to provide technologies, analytical products, and operational capabilities that meet users' needs and function in real-world settings.

A hallmark of Livermore's threat reduction work is its integrated approach to the complex and interconnected problems of WMD proliferation and terrorism. It addresses the full spectrum of threats—from preventing proliferation at its source, to detecting and reversing proliferant activities, to responding to the threatened or actual use of such weapons, to avoiding surprise regarding the WMD capabilities and intentions of others.

Because the materials required for nuclear weapons do not occur naturally, the best way to prevent nuclear proliferation or terrorism is to protect and control nuclear materials at the source. Major efforts are under way in Russia to secure or dispose of at-risk nuclear and radioactive materials. The starting materials for chemical and biological weapons, however, are ubiquitous and have many legitimate uses. Threat-reduction efforts must focus on identifying activities indicative of producing or acquiring chemical or biological weapons and on rapid detection, response, and recovery in the event of a terrorist chemical or biological attack. Still other activities are directed at understanding foreign weapons programs and developing advanced technologies for use by the U.S. intelligence and defense communities.

DHS Secretary Tom Ridge visits Livermore.

Science and Technology for Homeland Security

In March 2003, Congress established the Department of Homeland Security (DHS). In July, DHS Secretary Tom Ridge visited Livermore to see the Laboratory's counterterrorism technologies first hand and to talk with researchers from Lawrence Livermore and Sandia national laboratories about their work. During his visit, Secretary Ridge received updates on the National Atmospheric Release Advisory Center (NARAC), RadScout and nuclear incident response activities as well as BioWatch and biological detection programs at both Livermore and Sandia.

NARAC is a national emergency response service for real-time assessment of the transport and dispersion of nuclear, chemical, biological, or natural hazardous material released into the atmosphere. Its plume predictions are used by emergency response personnel in managing response operations and by emergency response planners in preparing for such emergencies. Since it was established in 1979, NARAC has responded to more than 80 alerts, accidents, and disasters and has supported nearly 1,000 exercises.

A NARAC emergency response team.

The Local Integration of NARAC with Cities (LINC) Program provides local emergency response agencies with direct access to NARAC's plume models and hazard predictions. To date, LINC connections have been established with Seattle, New York City, Fort Worth, Albuquerque, and Cincinnati. Fortuitously, LINC was operational in New York City in February 2003 and was able to assist the agencies responding to the Staten Island fuel barge fire. LINC is one of many examples of Livermore's efforts to partner directly with first responders to understand their needs and develop capabilities that meet those needs.

Lawrence Livermore is also working with state and local homeland security entities. In April 2003, the Laboratory hosted a Homeland Security Executive Summit, co-sponsored by Congresswoman Ellen Tauscher (California, 10th District) and the California National Guard. This summit brought together medical and emergency responders, military representatives, state and local officials, and researchers from the national laboratories to address issues of local preparedness in the event of a terrorist attack.

Biodetection Systems for Early Warning

One of the DHS's first acts was to launch the BioWatch early warning biodetection system at key cities across the nation. BioWatch is being operated through a partnership of federal, state, and local agencies. Key partners include DHS, the Centers for Disease Control and Prevention (CDC), the Environmental Protection Agency, and Livermore and Los Alamos national laboratories. Among other activities, the laboratories are providing technical expertise in biological detection as well as training assistance to state and local agencies.

BioWatch is based on the sample analysis technologies and concept of operations successfully demonstrated with the Biological Aerosol Sentry and Information System (BASIS). BASIS was developed jointly by Livermore and Los Alamos and deployed at the 2002 Winter Olympic Games in Salt Lake City and other high-profile events around the country. The heart of the BASIS field laboratory is the Cepheid Smart Cycler, which uses rapid miniature PCR (polymerase chain reaction) technology developed at and licensed from Livermore. This technology reduces the time for nucleic acid (that is, DNA) analysis from days or weeks to an hour or less.

Biodetectors are only as good as the assays they use to detect pathogens. Livermore has a significant effort in biosignatures, identifying regions of DNA or RNA unique to the pathogens of concern. These signatures are developed with the help of a novel bioinformatics system called KPATH, which uses advanced computational algorithms to identify unique sequences. Candidate signatures are carefully screened, and the most promising ones are developed into assays, which are then provided to the CDC for validation and, if successful, distribution to CDC's network of public health laboratories. Most of the signatures currently used by the BioWatch system were developed at Livermore. The Laboratory has also used its signature development capabilities to respond rapidly to several recent disease outbreaks. For example, in March 2003, candidate signatures for SARS (sudden acute respiratory syndrome) were developed within three hours of a request from the CDC.

Laboratory researchers are also working to develop the next generations to BioWatch. Deployments in the Albuquerque airport; the Washington, D.C., Metro; and a BART station in San Francisco demonstrated the effectiveness of the Autonomous Pathogen Detector System (APDS). APDS can operate in such venues for more than a week without human intervention, electronically

BASIS biosensor deployed in Times Square, New York City.

BASIS field laboratory.

Laboratory leaders join Representative Ellen Tauscher (California, 10th District) and Laboratory Director Michael Anastasio in opening the Radiation Detection Center.

RadScout radiation detector.

reporting results every hour, simultaneously performing up to 100 antibody-type assays, and performing confirmatory PCR on any samples that test positive with the antibody tests. Work is under way on a concept for rapid, reagentless mass-spectrometric analysis of airborne spores (such as those causing anthrax) and for highly multiplexed detection (hundreds of simultaneous assays) of viruses, toxins, spores, and vegetative bacteria. A new initiative is investigating the feasibility of detecting infection presymptomatically, well before exposed individuals know they are sick.

New Radiation Detectors

A ribbon-cutting ceremony in April 2003 marked the official opening of Livermore's Radiation Detection Center. The center serves as a focal point for scientists from across the Laboratory to come together to devise the improved radiation detection technologies needed to counter nuclear smuggling, for medical applications, and for scientific experiments to better understand the universe.

Livermore researchers have developed two new handheld gamma-ray detection and isotope identification instruments, RadScout and CryoFree/25. Their small size is achieved through innovative approaches to cooling the high-purity germanium detector without liquid nitrogen or large refrigeration units. They also incorporate software that analyzes the detected radiation spectrum and identifies the isotopes responsible. These detectors offer Customs, Border Patrol, and other inspectors the combination of portability, high resolution, high sensitivity, and spectral analysis—features not previously available in a single instrument. In June 2003, the Laboratory signed a licensing agreement for RadScout with ORTEC Products of Oak Ridge, Tennessee, in a ceremony at Livermore attended by NNSA Administrator Linton Brooks. In March 2004, the company unveiled its commercial product based on RadScout technology. This agreement is an example of how Livermore works with U.S. industry to move homeland security technology out of the laboratory and into the marketplace.

Laboratory researchers are also tackling the technically difficult problem of detecting smuggled uranium. Unlike plutonium, which emits readily detectable radiation, highly enriched uranium's emissions can be easily shielded, making it difficult to detect using current instruments. Livermore scientists have identified a radiation signature unique to highly enriched uranium based on high-energy gamma rays produced when the material is interrogated with neutrons. This signature is not found in normal background radiation and is detectable through the walls of typical cargo containers. With funding from the DOE Office of Science, experiments were conducted in 2003 at Lawrence Berkeley National Laboratory's 88-inch cyclotron that verified this signature and its predicted characteristics. Additional experiments were then conducted at Livermore using a standard cargo container provided by American President Lines to test the signature in realistic cargo-loading conditions.

Other Livermore researchers are testing systems that can detect, track, and characterize nuclear or radioactive material delivered on roads or waterways. In January 2003, as part of a demonstration project sponsored by the Defense Threat Reduction Agency (DTRA), two buoys containing a suite of gamma and neutron detectors were deployed at the waterway entrance to a U.S. Navy base. For the past year, Livermore has been collecting extensive data on the performance of these detectors in the harsh marine environment. In April 2003, the Detection and Tracking System, developed in partnership with the Remote Sensing Laboratory, was demonstrated near the entrance of a U.S. Army base. The system featured a new tracking algorithm that uses spectral signatures to correlate events detected throughout the network, source material identification capabilities, and a camera to take pictures of suspect vehicles to facilitate law enforcement operations.

International Threat Reduction

Throughout 2003, Laboratory scientists worked around the globe to reduce the threat of WMD proliferation. Livermore is a major participant in NNSA's Material Protection, Control, and Accounting (MPC&A) Program, which is helping Russia enhance the security of vast quantities of weapons-usable nuclear material. Comprehensive MPC&A upgrades continue at Chelyabinsk-70, one of Russia's two nuclear weapons design laboratories. Working with the Russian Navy, four nuclear weapon storage sites in the Kamchatka region are receiving comprehensive MPC&A upgrades. Work was recently begun with the Russian Ministry of Defense to secure hundreds of radioisotope thermoelectric generators in the Russian Far East. These generators contain large-curie quantities of strontium-90 and are used to power various operations in remote locations.

Livermore is assisting in various activities to develop nonweapons enterprises for former Soviet weapons workers. One such project is

Radiation detection test of a cargo container.

Radiation detection buoys.

establishing a positron emission tomography (PET) facility for cancer diagnostics at Snezhinsk (home of Chelyabinsk-70). This facility would be only the third such facility in all of Russia. Another project, a joint effort involving the Laboratory, Cyclotec Medical Industries in Lauderhill, Florida, and Biofil (a private company employing former weapons workers in Snezhinsk), has developed and put into production a transcutaneous electrical nerve stimulation device. This device, which treats acute pain noninvasively, recently won an R&D 100 Award.

Livermore seismic specialists and colleagues in the Middle East.

Laboratory scientists also participate in regional engagement activities, with a focus on regions where WMD proliferation is a concern. Projects are designed to provide technical assistance to regions on a multilateral basis, with the goal of bringing together the scientific communities from several countries in a region to work on specific technical issues. One ongoing project involves the exchange of seismic waveform data and seismic hazard information among Israel, Syria, Jordan, Iran, and other countries in the Middle East. For another project that includes scientists from Oman, United Arab Emirates, Qatar, and Saudi Arabia, Livermore helped deploy seismograph stations around the epicenter of a recent earthquake in Oman. Other projects are under way in South Asia (seismology) and in Central Asia (environmental remediation).

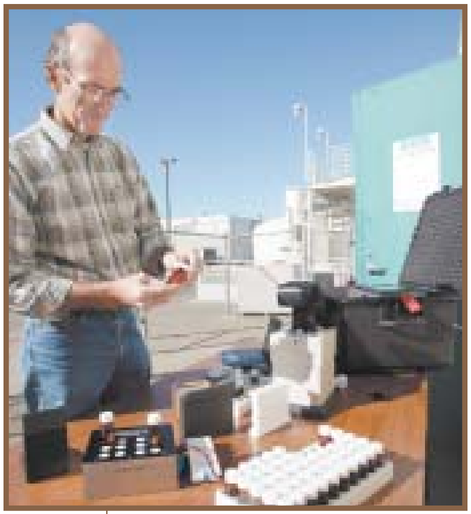
Supporting Military Operations

During 2003, the Laboratory provided multifaceted support to U.S. operations before, during, and after Operation Iraqi Freedom. Efforts included participation in International Atomic Energy Agency (IAEA) inspections in Iraq before the conflict began as well as deployment of several Laboratory employees to Iraq after the war to provide technical assistance to the Iraq Survey Group.

CAPS operations room supporting Operation Iraqi Freedom.

The Laboratory's Counterproliferation Analysis and Planning System (CAPS) team supplied 24/7 on-call support to the Defense Department throughout Operation Iraqi Freedom. CAPS also deployed a nuclear engineer, biotechnology engineer, and chemical engineer to the U.S. Central Command (CENTCOM) in Florida to lead DOE's collaborative WMD support team during the war. From mid-March to early May 2003, the CAPS team fielded roughly 200 requests for analysis, some that could be answered within a few minutes or hours and others requiring days of round-the-clock work. Developed and continually updated by the Laboratory, CAPS is a powerful modeling system for analyzing a country's WMD production processes and infrastructure and for assessing interdiction options and their corresponding consequences.

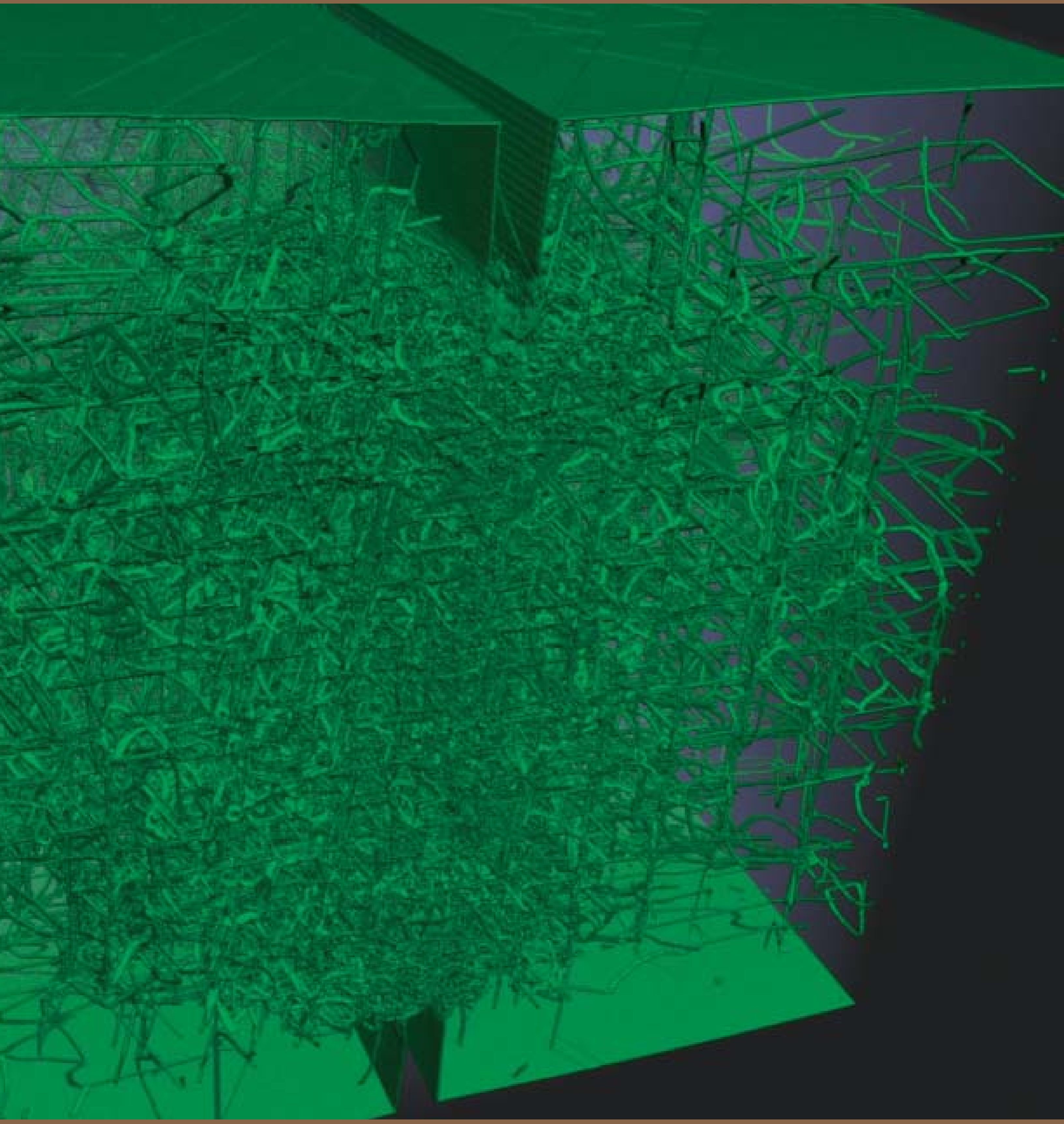
Many other projects at Livermore are aimed at meeting important needs of the U.S. military and other national security programs. The Laboratory's special capabilities are being used to devise novel sensors for challenging monitoring situations, secure high-bandwidth communications technologies, and advanced conventional munitions. Other efforts are developing powerful conflict simulation models and tools and methodologies for cyber security and information operations. Wherever appropriate, these technologies are transferred to end users or are commercialized. For example, the Laboratory recently licensed its field-portable, thin-layer chromatography (TLC) kit, for assessing the safety of munitions by analyzing the presence and quantity of stabilizers in propellant mixtures, to Ho'olana Technologies of Hilo, Hawaii. Kits went into production in 2003.



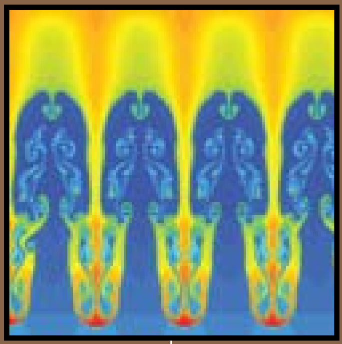
Kit for testing the safety of munitions.

Atoms for Peace: 50 Years Later

In a two-day symposium held at Livermore in November 2003, distinguished experts in science, technology, and policy examined how President Dwight D. Eisenhower's "Atoms for Peace" speech in 1953 affected the world. Eisenhower called on the nuclear states to help nations willing to forgo nuclear weapons acquire the benefits of civilian nuclear applications. A wide range of views were expressed at the symposium on the future prospects of nuclear technology—both benefits and risks—and the interrelationship between defense and civilian applications of nuclear energy. In the keynote talk, Susan Eisenhower, chairwoman of the Eisenhower Institute and granddaughter of President Eisenhower, combined warm personal reflections with insightful policy perspectives. (Eisenhower is shown below right with Ron Lehman, director of the Laboratory's Center for Global Security Research [CGSR].) The symposium wrapped up a year-long study sponsored by the CGSR. The Atoms for Peace after 50 Years project included exploratory workshops in Livermore, Japan, and France; a conference in Washington, D.C.; the two-day symposium at Livermore; and a final report, which is available at http://cgsr.llnl.gov/.

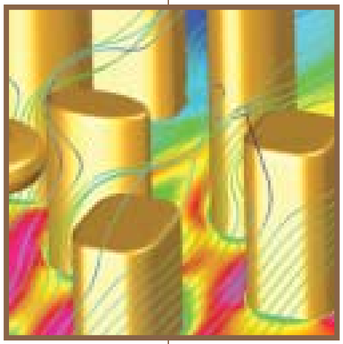


Dislocations lead to ductile failure in a simulation of copper metal under strain.

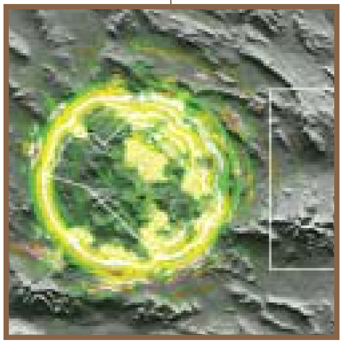


Hydrodynamic instability calculation.

Meeting Enduring National Needs



Model of atmospheric dispersion in a cityscape.



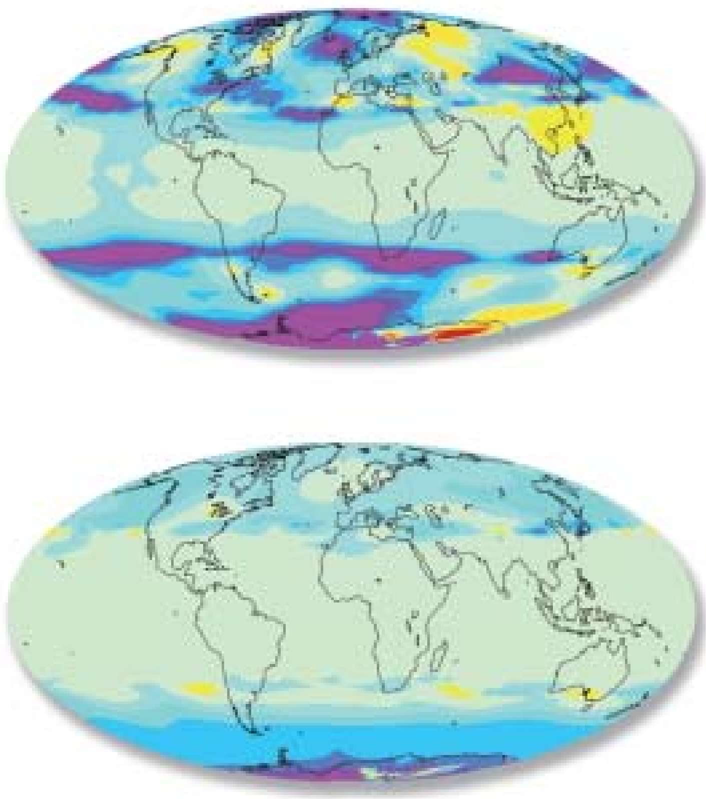
Model of seismic energy moving in a complex geology.

As part of its overarching national security mission, the Department of Energy pursues research and development in areas of enduring importance to the nation. DOE mission priorities in energy and environment, bioscience, and fundamental science and applied technology are supported by Laboratory researchers. Livermore seeks challenges that reinforce its national security mission and have the potential for high-payoff results.

Long-term research is needed to provide the nation with abundant, reliable energy as well as a clean environment. Livermore's energy and environmental programs contribute to the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reducing risks to the environment.

Bioscience research at Livermore enhances the nation's health and security. Projects in molecular biology, genetics, computational biology, biotechnology, and health-care research leverage the Laboratory's physical science, computing, and engineering capabilities. Research is directed at understanding the causes and mechanisms of ill health, developing biodefense capabilities, improving disease prevention, and lowering health-care costs.

Livermore also pursues initiatives in fundamental science and applied technology that reinforce the Laboratory's strong research expertise. Many projects, sponsored by DOE's Office of Science and other customers, take advantage of the unique research capabilities and facilities at Livermore. Other work, supported by Laboratory Directed Research and Development funding, extends the Laboratory's capabilities in anticipation of new mission requirements.



Data for change in tropopause height (top) resemble simulation for the same period (bottom).

Modeling Human Effects on Global Climate Change

Computer simulations and data gathering by Livermore researchers are contributing to worldwide efforts to better understand the history of the Earth's climate, changes due to human activities, and methods for mitigating the harmful effects.

An international team of scientists, led by researchers from Livermore, has discovered that emissions from human activities are largely responsible for a significant increase in the height of the tropopause, the boundary between the troposphere and the stratosphere. Their results appeared in *Science*. The research was based on advanced climate models showing that human-induced changes in ozone and well-mixed greenhouse gases are the primary causes of the approximately 200-meter rise in the tropopause that has occurred between 1979 and 1999. Another team has discovered that satellite data used to measure temperature changes in various layers of the atmosphere contain uncertainties that may hamper the detection of human effects on climate change.

An article in *Nature* describes Livermore research on the effects of carbon dioxide on Earth's oceans. Models revealed that continued release of carbon dioxide during the next several centuries would increase ocean acidity more rapidly than during the past 300 million years, resulting in damage to marine life. Oceanic absorption of carbon dioxide had been viewed as beneficial because it removed greenhouse gases from the atmosphere. However, the increased acidity may damage marine organisms such as coral reefs, calcareous plankton, and sea life with calcium carbonate skeletal material. Organisms living in the deep sea may be particularly sensitive to increased ocean acidity.

A Year for Celebration in Genomics

In May 2003, the Human Genome Project, including DOE, the National Institutes of Health, and other laboratories around the world, declared its task of sequencing the human genome complete. The largest biological project ever undertaken, the Human Genome Project determined the sequence of the genome's three billion DNA base pairs. DOE's Joint Genome Institute (JGI) in Walnut Creek, California—a consortium formed by Lawrence Livermore, Lawrence Berkeley, and Los Alamos national laboratories—sequenced chromosomes 5, 16, and 19, which together constitute 11 percent of the human genome. JGI is currently sequencing about 2 billion base pairs per month for the study of a variety of organisms.

Also during the spring of 2003, celebrations around the world feted the 50th anniversary of Watson and Crick's discovery of the double helix structure of DNA, the "molecule of life." And Livermore marked the 40th anniversary of its Biology and Biotechnology Research Program, which has been an active participant in genome sequencing and the many research endeavors that have spun off from that effort.

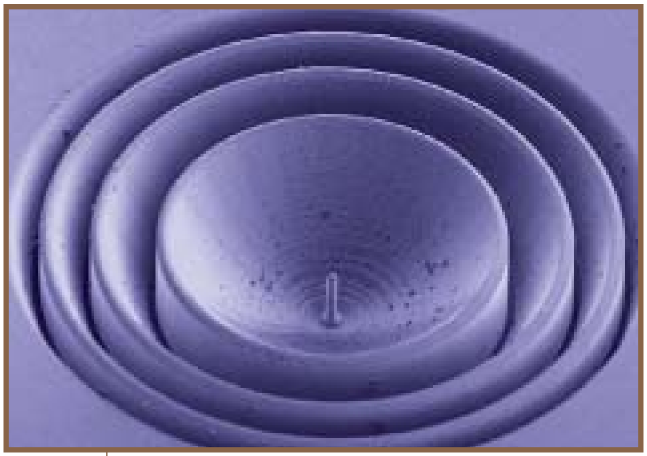
Analysis at JGI of the genomes of several microscopic ocean-dwelling organisms is providing new insights into how the planet's oceans affect its climate. Comparative studies of four types of cyanobacteria—"photosynthetic" microbes that derive energy from sunlight, just like plants—were published in *Nature* and the *Proceedings of the National Academy of Sciences*. Three of the microbes were among the first organisms to have their DNA sequenced at JGI in the late 1990s and were the first ocean bacteria to be sequenced. Cyanobacteria are the smallest, yet most abundant photosynthetic organisms in the oceans, and they play a critical role in regulating atmospheric carbon dioxide, a major contributor to global climate change. Two of the cyanobacteria remove about 10 billion tons of carbon from the air each year, or two-thirds of the total carbon fixation that occurs in oceans.

Joint Genome Institute.

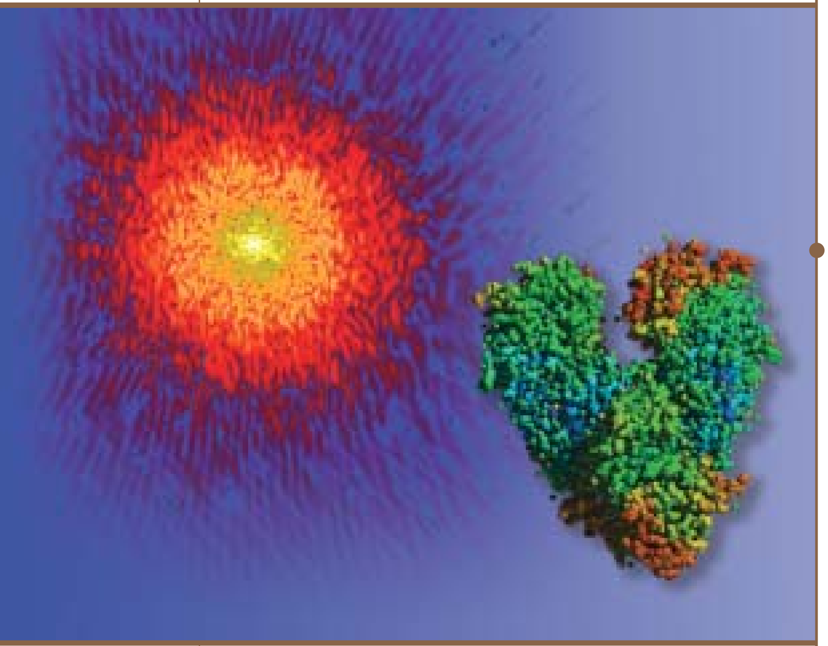
Center for Accelerator Mass Spectrometry.

Measuring and Understanding Radiation Dose

New Laboratory research reaffirmed the accuracy of a 1986 study of radiation absorbed by survivors of the atomic bombs dropped on Hiroshima and Nagasaki. The controversial study had determined an absorbed dose that was much higher than earlier estimates. A computer-based search of Livermore's nuclear data libraries revealed that the reaction of neutrons on copper to produce nickel-63, which has a 100-year half-life, could still be detected and quantified today, more than 50 years after the event. But because the nickel-63 content is less than one million atoms per gram of copper, it first took Livermore scientists three years to develop a method that could isolate the nickel-63. Lightning rods, rain gutters, and copper roofing materials collected as far as 5,000 meters from the epicenter of the Hiroshima blast provided samples that were analyzed by the highly sensitive mass spectrometer at Livermore's Center for Accelerator Mass Spectrometry. The quantities of



Prototype focusing lens for the Linac Coherent Light Source.



Simulated diffraction pattern and model of the lethal-factor protein of an anthrax spore.

remaining nickel-63 revealed absorbed doses that were consistent with the 1986 findings, except at the closest distances. The study suggests that these results may be consistent with a slightly underestimated height-of-burst for the Hiroshima bomb.

Livermore has also performed some of the first research into the effects of low-level ionizing radiation. Using laboratory mice and human cell cultures, experiments show that a low-level dose causes cells to activate genes that specialize in repairing damaged chromosomes, membranes, and proteins and in countering cellular stress. The activity of these cells is not simply a reduced level of that seen in cells exposed to high doses of ionizing radiation. Rather, many genes are called into action in response only to low doses of radiation.

Developing Tools to Image Molecular Dynamics

Intense sources of light are essential for Laboratory advances on several fronts—from the imaging of biological molecules to the study of materials in weapons at extreme conditions. Innovations by Livermore researchers are contributing to the development of light sources that are brighter, faster, and more energetic than current capabilities.

A next-generation light source, the Linac Coherent Light Source (LCLS), is being designed for installation at the Stanford Linear Accelerator Center (SLAC). Livermore is part of the SLAC-led consortium to plan, design, and build the LCLS. When it becomes operational in 2008, LCLS will be the world's first large-scale x-ray laser. Its x-ray beam will be as much as 10 billion times brighter than that of any x-ray light source available today. The light will last for only quadrillionths of a second, allowing the beam to capture the dynamic motion of molecules.

Livermore's primary responsibility is to design and fabricate the optics that will transport the x-ray beam to experimental chambers and to diagnose the beam's condition. Because of its extreme brilliance and ultrashort duration, a single x-ray pulse can melt many materials, which makes designing optical systems a challenge. Incorporating significant design innovations, Laboratory researchers are making great strides in developing a high-resolution camera for beam diagnostics, optical devices to redirect the beam, and focusing lenses that will not be damaged. Other

Livermore scientists are examining possibilities for LCLS experiments and developing techniques for analyzing the diffraction data that will be produced by experiments.

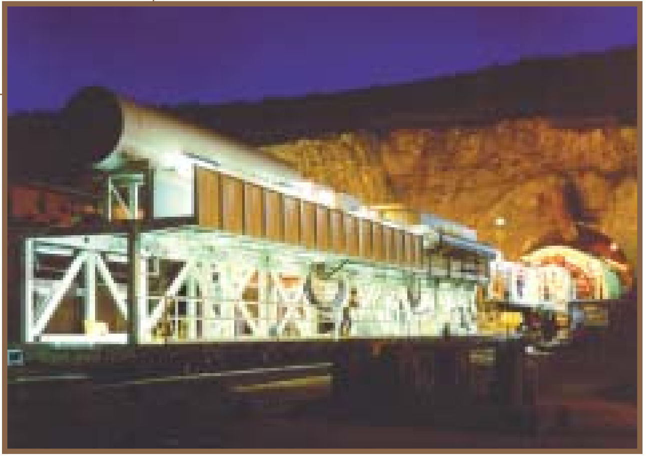
X-ray imaging is also the goal of the Picosecond Laser-Electron Inter-Action for the Dynamic Evaluation of Structures (PLEIADES) project. The PLEIADES team has succeeded in creating high-brightness x rays (known as Thomson x rays) by colliding an energetic electron beam with a high-intensity laser. In January 2003, the first 70-kiloelectronvolt light was produced in experiments using the Laboratory's 100-megaelectronvolt linear accelerator and FALCON laser. Supported by Laboratory Directed Research and Development funding, work continued in 2003 to increase x-ray production by improving the quality of the laser and electron beams and to prepare to conduct diffraction experiments. The goal is to use the extremely short burst of x rays, from 1 picosecond (10^{-12} seconds) to 100 femtoseconds (10^{-13} seconds) long, to image a variety of physical, chemical, and biological dynamic phenomena. Of particular interest will be experiments in which a strong shock is applied to a sample of dense material whose properties are then probed.

Linear accelerator used for PLEIADES.

Other Laboratory scientists are using an extremely short pulse (10 trillionths of a second), high-power (100-terawatt) laser to create a focused beam of high-energy protons that could be used to rapidly heat and then image targets. These JanUSP laser experiments are described on p. 11.

Materials Testing and Modeling for the Yucca Mountain Project

Yucca Mountain Project.



A team of Livermore researchers is testing and refining the design and materials for what may eventually be 12,000 nuclear waste packages as part of DOE's program to design, license, and build an underground nuclear waste repository in Yucca Mountain, Nevada. Currently, DOE is preparing an application to obtain a Nuclear Regulatory Commission license to proceed with construction of the repository. The Laboratory is focusing on developing the engineered barrier system. This system consists of a waste package, drip shield, and supporting structures. The engineered barrier system is designed to work with the natural barriers of Yucca Mountain to contain the repository's radioactive wastes and prevent them from seeping into the water table, which lies about 300 meters below the planned repository.

Prototype waste package (top) and the Long-Term Corrosion Test Facility (bottom).

In the current repository design, waste will be stored in a package consisting of corrosion-resistant metal (Alloy 22) and an inner canister made of a tough, nuclear-grade stainless steel (316NG). An overhanging drip shield made of titanium will give added protection from dripping water and any rocks falling from the repository ceiling. To gather information about how these materials will behave over thousands of years, researchers are conducting accelerated aging tests at the Laboratory's Long-Term Corrosion Test Facility. Some 20,000 test specimens are now being or have been exposed to the range of conditions expected to occur in the repository. In addition, in analyses that require the Laboratory's supercomputers, scientists are simulating the geologic evolution of the repository to predict the temperature evolution surrounding the buried waste and explore the possible means by which water could enter the repository tunnels over geologic time periods.

Progress in Magnetic Fusion Energy Science

In 2003, Laboratory researchers advanced magnetic fusion energy science through computational and experimental work performed primarily for DOE's Office of Science. Livermore collaborates in experiments using the DIII-D Tokamak at General Atomics in San Diego. Researchers also develop advanced computational models to study turbulence and other physical phenomena at the edge of the plasma. Building on the success achieved with these models, Laboratory scientists are undertaking the challenge of developing a first-principles model of the edge of high-performance tokamak plasmas, a region of steep temperature and density gradients. Results will have important implications for the performance of the International Thermonuclear Experimental Reactor (ITER), a major international project with significant U.S. participation.

The Sustained Spheromak Physics Experiment.

In addition, Livermore is the site of the Sustained Spheromak Physics Experiment (SSPX), an alternative to the tokamak concept that may lead to lower-cost fusion reactors because of the spheromak's compact size and reduced complexity. Performance of the SSPX has increased significantly in the past few years. The pulse length has been extended to 4.5 milliseconds, and plasmas have been produced with low impurity content, high temperatures (over 240 electronvolts), and high plasma pressure. In 2003, SSPX researchers were selected to be part of the National Science Foundation Physics Frontier Center for studies in magnetic reconnection.

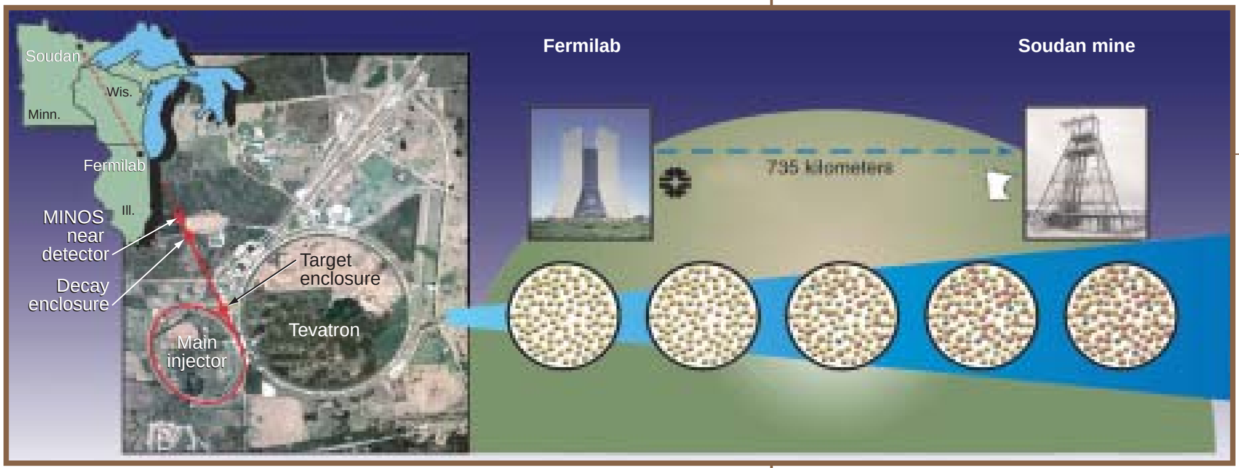
Experiments to Unravel the Nature of Matter

Livermore is engaged in a variety of large international physics projects, providing expertise in the underlying physics, sophisticated data analysis capabilities, and critically needed engineering solutions to challenging problems. For example, the Laboratory took the lead in design work—and devised the solution that was implemented—for steel detector planes for Fermi National Laboratory's Main Injector Neutrino Oscillation Search (MINOS) experiment. Because neutrinos are extremely difficult to observe, the detector required 450 steel planes, each 8 meters in diameter and weighing 10,000 kilograms. The planes had to be lowered 800 meters down a mine shaft only 2 meters across. In 2003, the detector system was assembled in a former iron mine in Soudan, Minnesota, and the MINOS experiment is expected to be up and running in early 2005.

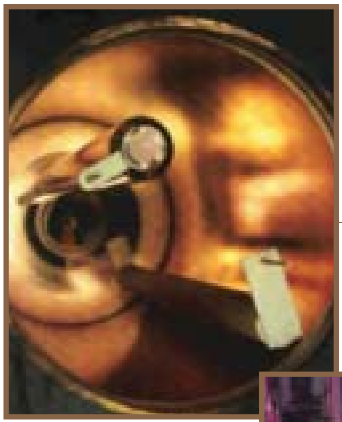
MINOS, which involves more than 200 scientists from many institutions, aims to look for neutrino oscillations (changes from one type of neutrino to another) as an explanation for why there are "missing neutrinos" in studies of cosmic rays and the energy output of the Sun. From Fermilab's home in Illinois, an intense beam of neutrinos will be directed toward Soudan, 735 kilometers away. Despite its immense size, the MINOS apparatus will be able to detect only about 9,000 of the 5 trillion neutrinos produced at Fermilab during each year of the experiment.

In more modest experiment, researchers at the Livermore site are engaged in the search for another elusive particle—the axion. This particle, if found to exist, would help "balance the budget" for the missing mass in the universe and clear up one of the thorniest issues in particle physics. The experiment is searching for the

Detector planes for MINOS neutrino detector.



From Fermilab to the MINOS detector.



Axion detection experiment.

decay of an axion into a single photon in the presence of a strong magnetic field, which is provided by a 6-ton superconducting coil.

After Livermore's Laboratory Directed Research and Development Program provided the necessary groundwork, the Livermore axion experiment began in 1995 with funding from DOE's Office of Science. The team includes researchers from the Laboratory, the University of Florida, the University of California at Berkeley, and the National Radio Astronomy Observatory. No axion decays have yet been detected, setting an upper limit on the cosmic density of axions. The next generation of axion detectors at Livermore, which are being planned, should be able to answer the question of whether axions exist.

A Sharper View of the Universe

On September 20, 2003, scientists at the W. M. Keck Observatory on Mauna Kea, Hawaii, used a laser developed by the Laboratory to create an artificial guide star on the Keck II 10-meter telescope. With the guide star, researchers can make fuller use of the telescope's adaptive optics system, which was also developed by Livermore scientists and installed in 1999.

Laser creates an artificial guide star at the Keck II telescope.

Adaptive optics allow astronomers to minimize the blurring effects of Earth's atmosphere, producing images with unprecedented detail and resolution. The system uses light from a relatively bright star to measure distortions caused by the atmosphere and then correct for them. But only about 1 percent of the sky contains stars sufficiently bright to be of use. By using a laser to create a virtual star, astronomers can study much fainter objects, increasing coverage to more than 80 percent of the objects in the sky. Laser guide stars have been used on smaller telescopes, but this is the first successful use on the current generation of large telescopes.

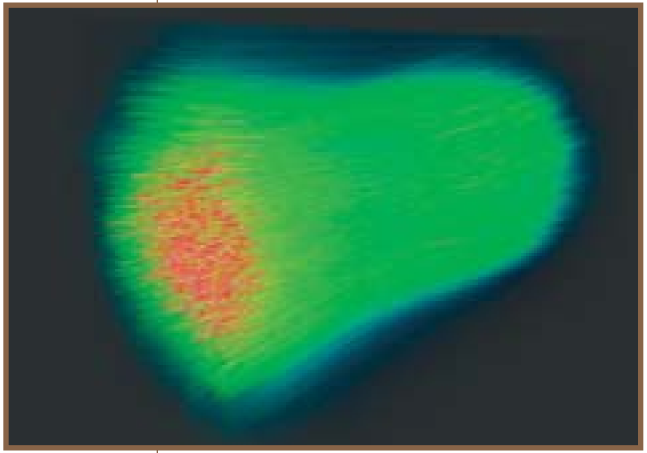
Major New Computers Augment Livermore's Capabilities

Since 1996, the Laboratory has made institutional investments, leveraging the ASC Program (see p. 12) to provide powerful computers for use by researchers in all programmatic areas. Because of this effort, called the Multiprogrammatic and Institutional Computing (M&IC) Initiative, Livermore has assumed a leadership position in the development and application of new classes of low-cost, reliable, high-performance production computers. Central to M&IC's achievements have been the development of strategic relationships with key vendors and the prototype application of their extraordinarily low-cost systems to scientific problems. Prior M&IC successes motivate vendors to bid new systems aggressively to the Laboratory, as success at Livermore becomes part of their marketing strategy. This further drives down cost, leads to more achievements, and gives the Laboratory options to explore additional paths to extremely low-cost computers that might operate in the petaops range. An important science and technology thrust area for the Laboratory is the development of petaops-scale simulations and the invention of better tools for mining data and integrating experiments and simulations (see p. 12).

As an example of this strategy, M&IC has recently focused on acquiring low-cost Linux clusters. By leveraging ASC-developed software and technology, Livermore has been at the leading edge in using these as high-capability computers for production runs of science and engineering simulation models. The first such system to gain national recognition was the Multiprogrammatic Capability Resource (MCR) supercomputer, capable of 11.2 teraops. This system was integrated in Utah in summer 2002 and started running large-scale applications in December. In the June 2003 Top500 supercomputing list, MCR was ranked as the world's third fastest computer. The machine has been used as a production resource since August 2003 and dramatically increased Livermore's unclassified computing capability.

The 11.2-teraops Multiprogrammatic Capability Resource (MCR) supercomputer.

Competition for access to the MCR rapidly saturated the machine. In part because of this, Livermore is procuring a far more powerful system called Thunder. This machine, integrated by California Digital Corporation, features a peak speed of 22.9 teraops and uses 1,024 high-performance Intel Tiger-4 nodes with four Itanium 2 processors and 8 gigabytes of memory each. The Laboratory is partnering with Intel to improve the compiler, as this is a key element of achieving high performance. The machine is expected to move into full production in summer 2004.

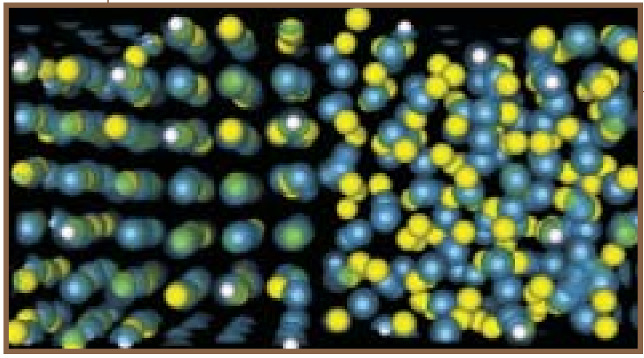


MCR simulation of a National Ignition Facility laser beam passing through a hot plasma.

First-Principles Simulations

First-principles simulations, based on fundamental properties of matter derived from quantum mechanics, are providing a new avenue for exploring properties of condensed matter in extreme conditions. Because these simulations do not rely on any empirical or adjusted parameters, they are capable of making much needed

First-principles simulation of lithium hydride shows coexistence of solid phase (left) with liquid phase (right).



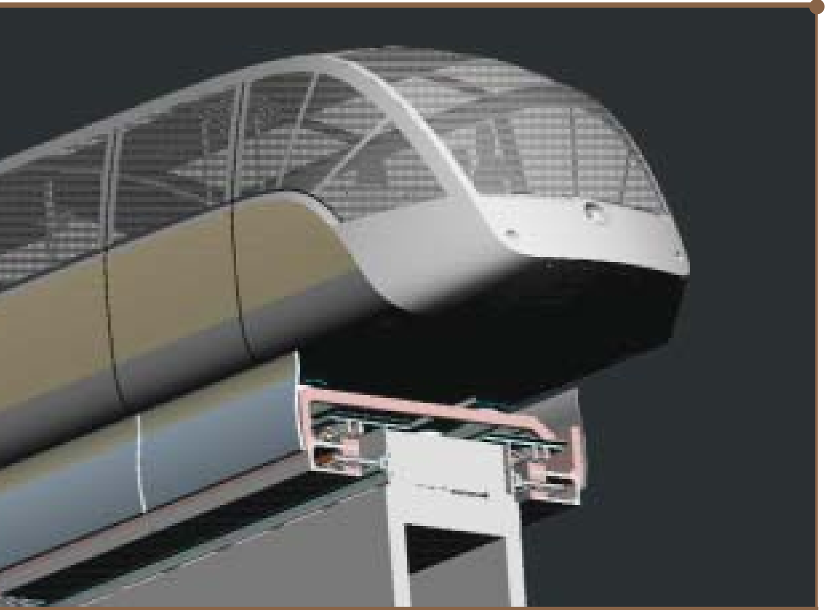
theoretical predictions. A substance's physical properties often change drastically when it is subjected to pressures reaching millions of atmospheres. Hence, an experimental determination of these properties is often complex and expensive.

The first-principles simulation code GP developed at the Laboratory has been used to study the properties of fluids at high pressure. In 2003, an important new capability was added to GP. For the first time, it was possible to accurately simulate the solid–liquid interface of a molecular substance at high pressure and high temperature with a first-principles approach. Using this new method, Livermore scientists were able to predict the melting properties of lithium hydride up to a pressure of 200 gigapascals. Results were published in *Physical Review Letters*.

Maglev on Track for Urban Transportation

Conceived by a Livermore physicist, the Inductrack magnetic levitation (maglev) system for urban and high-speed transportation is moving down the development track. In May 2003, General Atomics (GA) broke ground at its San Diego facility for a 120-meter-long track to conduct a full-scale demonstration. The project is sponsored by the federal government to showcase a new generation of urban transportation technology. GA and the Laboratory have signed a licensing agreement for use of the levitation technology in magnetic levitation train and transit systems.

Inductrack uses unique configurations of powerful, permanent magnets, called Halbach arrays, to create its levitating fields. It offers the promise of safer, cheaper, and simpler means to levitate urban and high-speed trains. While work on the demonstration effort proceeds in San Diego, the Livermore team is optimizing the design of the magnets and the track. In particular, the team is working on a revised design for the track, which is even simpler and should be less expensive to manufacture than the original.



Front end of the urban maglev vehicle.

Award-Winning Laser Technologies Benefit Industry

Innovative laser technologies developed at Livermore are improving processes used to manufacture aircraft parts. In 2003, Livermore and its industrial partner, New Jersey–based Metal Improvement Company, Inc., received an R&D 100 Award for a laser process for forming thick, curved metal parts. Called Lasershot™ Precision Metal Forming, the technique is especially effective for forming pieces greater than 2 centimeters thick—pieces so thick that they are difficult to shape by other means without weakening the material structure.

Lasershot™ Precision Metal Forming shapes parts to exact curvature and contour specifications, preserves a smooth surface finish, and leaves the parts resistant to stress corrosion cracking and failure from fatigue. The technique uses a solid-state laser system that induces a deep level of compressive stress on a section of metal, which elongates the treated surface, effectively bending the metal within the processed area. The process can be applied to any metal or alloy and is particularly effective with the aluminum alloys used for structural aircraft components. It can also be used to precisely form the final shape of nuclear waste canisters, which could be used in the Yucca Mountain waste repository program.

Developers of Lasershot™ Precision Metal Forming, which won a 2003 R&D 100 Award.

Six R&D 100 Awards in 2003

Livermore scientists and engineers earned 6 R&D 100 Awards for outstanding achievement in research and development. Each year *R&D Magazine* presents awards to the top 100 industrial, high-technology inventions submitted to its competition. The Laboratory's award winners (listed on p. 44) will have applications in laser machining, computer-chip manufacturing, high-power lasers, health care, and the war on terrorism. They bring to 97 the number of R&D 100 Awards that Livermore researchers have won.

A team of scientists from three national laboratories—Livermore, Sandia, and Berkeley—and one company, Northrop Grumman Space Technology/Cutting Edge Optronics, also received one of three Editor's Choice awards for the most outstanding achievement among award winners. Their Extreme Ultraviolet Lithography (EUVL) Full-Field Step-and-Scan System was honored for making the "greatest improvement upon an existing technology" for advancing the field of lithography.

Front view of the EUVL Full-Field Step-and-Scan System.

Outreach programs with historically black colleges and universities bring students to the Laboratory.

School tours of the Laboratory's Discovery Center are popular events.

Shaping the Laboratory's Future

For more than 50 years, the Laboratory has provided an environment that attracts a high-quality workforce motivated by "a passion for mission" and dedicated to scientific and technical excellence. Livermore's many accomplishments in 2003 are the products of visionary individuals and exceptional multidisciplinary team efforts. They carry forward a long tradition at the Laboratory—innovations in science and technology and delivery to sponsors of markedly improved capabilities to meet pressing national needs.

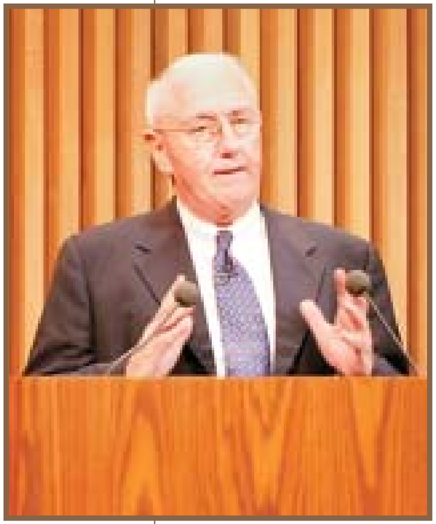
Livermore's most valuable asset is its workforce. The Laboratory stays vibrant by continuing to attract an outstanding staff. Strong ties to world-class research universities—in particular, many partnerships with the various campuses of the University of California—serve as a vehicle for bringing to the Laboratory new talent and the latest breakthroughs in science and technology. Livermore's long-standing ties with the University have also fostered a tradition of intellectual independence and integrity as well as a focus on the long-term interests of the nation. Laboratory researchers strive to anticipate future national security needs. Science and technology investments and exploratory research and development efforts are targeted accordingly.

A healthy future also requires that the Laboratory conduct operations in a safe, secure, and efficient manner. Protection of sensitive information, nuclear materials, and other valuable assets is of paramount importance, as are the health and safety of the public and Livermore employees. Contributing to a safe, clean environment is only part of being a good neighbor. The Laboratory and its staff participate in a wide range of civic endeavors and broadly contribute to the University of California's mission of education, research, and public service.

Demonstrating Laboratory science during Family Day.

Laboratory employee serving as judge at a local Science Fair.

Robert C. Dynes, President of the University of California (right) with UC Regent John Davies and former President Richard Atkinson.



UC Vice President for Laboratory Management, Retired Admiral S. Robert Foley.

University of California Management Changes and Contract Competition

In June 2003, the University of California (UC) Board of Regents selected Robert C. Dynes to become the 18th president of UC, effective October 1. Soon after Dynes took office, Retired Admiral S. Robert Foley was named UC Vice President for Laboratory Management. Foley, a longtime naval commander and consultant on energy and defense issues, is responsible for the University's management and operation of Berkeley, Livermore, and Los Alamos national laboratories. UC has managed the three laboratories on behalf of the federal government since their inception. The University has provided the stable, special environment that has enabled the laboratories to achieve remarkable scientific advancements and vital contributions to national security.

President Dynes and Admiral Foley assumed leadership at a time when the future of UC's management of the laboratories is uncertain. In April 2003, DOE Secretary Spencer Abraham announced his intention "to open the management of Los Alamos to full competition when the current contract expires." Subsequent congressional legislation required that the contract to manage and operate Lawrence Livermore also be subject to open competition at an as-yet undetermined future date.

Soon after the decision was made to compete the Los Alamos contract, NNSA Administrator Linton Brooks visited Livermore and talked to employees about DOE's decision. Brooks said both he and the Secretary of Energy want UC to join in the competitive process, with Brooks adding "if I get the [bidding] criteria that values science right, I am confident we will get UC or better" to bid. The UC Board of Regents has not made a decision whether to compete for the Livermore and Los Alamos contracts, but the University has taken actions to preserve its options and to continue to prepare as if it will compete. In a visit to Livermore in November 2003, President Dynes and Admiral Foley expressed optimism about UC's continued role in managing the laboratories.

Validation of Laboratory Business Practices and Operations

In January 2003, the Laboratory Director began an examination of key areas of the Laboratory’s operations. His goal was to provide reassurance that business policies and practices are sound and to make improvements wherever necessary. In both scientific work and day-to-day operations, Laboratory employees expect to be accountable to high standards. However, events in late 2002 at Los Alamos called into question the standards of business operations at the UC-managed national laboratories.

Laboratory actions included a thorough reanalysis of policies, procedures, and processes; a “wall-to-wall” property inventory; an internal audit of property and procurement systems; and an external third-party review of business systems. These efforts verified that Livermore is following prudent business practices that include appropriate checks and balances. In particular, the external review, conducted by a team from Ernst & Young LLP, provided an independent assessment and operational analysis of select business processes at the Laboratory. Based on two months of observation and operation analysis, the Ernst & Young team validated the existence of appropriate internal controls at Livermore and did not disclose any material weaknesses in this system of controls.

Improving the Workplace and Attention to Staff Needs

Ensuring the continuing vitality of the workforce is a high priority for Laboratory management. In response to staff needs, a wide range of actions are under way to improve the workplace and help employees manage the balance between their jobs and the rest of their lives. These needs were identified in a formal survey conducted for the Laboratory to understand the issues facing employees and to assess their views. Survey Action Teams were formed to recommend improvements in response to survey results, and Laboratory senior management is acting on these recommendations.

Safety First

Environment, safety, and health (ES&H) considerations are an integral part of project planning and work execution at the Laboratory. The health and safety of the public and Livermore employees are of paramount importance—as is environmental quality. The Laboratory sets high expectations for the ES&H performance of employees and has put into place effective systems and procedures, which are continually improved, to ensure that safety standards are met. Livermore's Integrated Safety Management System provides a framework through which safety procedures and practices have markedly improved, just as safety performance has. A notable example is the outstanding safety record compiled by the National Ignition Facility construction project, which has logged more than 3.7 million hours of work without a lost workday accident.

National Ignition Facility workers celebrate their latest safety milestone in 2003.

An employee tests products in the Ergonomic Demo Room.

One result of the survey was the Integrated Pay and Performance Program (IPPP), the largest revision of Livermore's performance appraisal, ranking, and pay system in the last two decades. This new program is a significant step in answering employees' requests for a better system while meeting the needs of management to successfully assess and reward employee contributions. The program is designed to be more consistent and less complex than previous performance management approaches. IPPP links total contribution to Laboratory programs and operations more directly to pay, and it holds management accountable for effective program implementation.

In response to employee input, the Laboratory is providing additional career development and training programs and has instituted flexible work schedule options. Expanded work/life services are also available to employees, ranging from child care to programs for financial and estate planning. One example is the opening of a new Ergonomic Demo Room at the Laboratory. The room is stocked with samples of ergonomic products that employees can select to meet their workplace needs, based on an evaluation by one the Laboratory's ergonomic specialists.

Groundbreaking for the new Central Café.

Survey results also pointed out the need for an expanded cafeteria in the growing northeast quadrant of the Laboratory. Construction started on a new Central Café in April 2003, and it opened for business in early 2004. The new café can serve nearly twice the number of daily lunches as the facility it replaces, and it provides marked improvements in operational efficiency and the overall dining atmosphere.

Security Enhancements at the Laboratory

Additional security measures on East Avenue.

Protection of sensitive information, nuclear materials, and other valuable assets at Livermore is critically important. Since September 2001, the Laboratory has routinely functioned under heightened security levels. An extensive apparatus is in place, and upgrades are continually made to address new threats and concerns. An example is the change to controlled access of a one-mile stretch of East Avenue that runs between Lawrence Livermore and Sandia national laboratories. Implemented in August 2003, this added measure of security had become much more urgent in the wake of 9/11. Planning for and completing the change, which entailed integrating the needs of adjoining landowners, was undertaken with the full cooperation of the City of Livermore and Alameda County.

Earlier in 2003, some security mistakes were made—missing keys and a lost access badge—and they were compounded by management and communication issues in the security department. The Laboratory Director at once made clear to all employees the importance of dealing directly and immediately to fix mistakes and problems that arise. Sustaining public trust in the institution requires Laboratory employees to exercise vigilance to prevent security incidents and to respond appropriately when incidents do occur.

The Director also announced a major reorganization of the Safeguards and Security Department at the Laboratory and selected a new leader for these activities. The new leader first implemented the necessary corrective actions following the security incidents. His Safeguards and Security organization worked closely with external review teams investigating the incidents. He also directed an evaluation of Livermore's security management structure and recommended changes to the Director. The organization's self-improvement efforts—and the professionalism of its staff—greatly contributed to the high marks achieved in a special security review conducted in early 2004 by DOE's Office of Independent Oversight and Performance Assurance. The two areas that were formally rated, cyber security and protective force, received an "Effective Performance" grade, the highest rating the office assigns.

Security police officers train regularly to protect Laboratory personnel and property.

A New Science and Technology Investment Strategy

At the beginning of 2003, the Deputy Director for Science and Technology launched an effort to take a fresh look at Livermore's science and technology (S&T) investment strategy. Outstanding S&T makes it possible for the Laboratory to take on demanding missions and be ready for future national challenges. Sustaining this S&T vitality requires continual reinvestment in research capabilities and facilities, and, above all, in the people who make it possible.

A broad spectrum of Laboratory scientists and engineers participated in the first phase of the planning process, which was completed in 2003. As a result of their work, new initiatives are under way that enhance Livermore's capabilities to carry out current programs, pursue discovery-class science and innovative technologies, and enable future missions of national importance.

The strategy builds on the enormous investments that have been made at Livermore in the National Ignition Facility and

Nano secondary-ion mass spectrometer was one of many recent S&T investments.

high-performance scientific computing. It also aims to invigorate the Laboratory's experimental capabilities to meet the growing demand of research programs for data and nanoscale science and engineering. The strategy, which will continue to be revised and updated, recognizes the importance of sustaining an agile and flexible environment for research and development to support emerging national needs.

Decontamination and Waste Treatment Facility (top) and patented process for encapsulating contaminants from used HEPA filters (bottom).

A Major New Facility for Waste Management

Livermore's Decontamination and Waste Treatment Facility (DWTF) began operations in September 2003. DWTF is a new, integrated facility for storing and processing the Laboratory's wastes, whether they be hazardous, low-level radioactive, transuranic radioactive, or mixed (that is, both chemically hazardous and radioactive). The new facility is a complex of buildings that includes new indoor storage areas and a California-permitted treatment plant. A 2,200-square-meter building houses solid-waste processing facilities, and a 1,600-square-meter building is used for liquid waste processing. The centerpiece of the liquid waste processing building is an enormous enclosed "tank farm" with nine 18,000-liter, closed-top tanks.

DWTF greatly enhances the Laboratory's capabilities to provide safe, cost-effective waste operations. The facility is also key to Livermore's efforts to develop and improve ways of managing generated wastes. An example of waste-management improvements is the development by Laboratory researchers of a patented process that encapsulates contaminants in used high-efficiency particulate air (HEPA) filters. The new process is easy to use, safe, and does not generate secondary waste as other processes do. HEPA filters are used at facilities throughout the DOE weapons complex so the potential benefits are significant.

A Good Neighbor

More than 180 community guests toured NIF and the DWTF as part of the Laboratory's annual Community Leader Day. It was an opportunity for elected officials, city leaders, school board members, and police and fire officials to learn more about the Laboratory. The Laboratory Director discussed the many ways that the institution and its employees reach out to the community. One example was the establishment of the Homeland Security Organization to help federal, state, and local officials fight terrorism. At the DWTF, community members learned what waste products are produced and how wastes are handled and treated safely without harming those inside or outside the Laboratory fence.

The Laboratory's annual campaign to Help Others More Effectively (HOME) raised more than $1.5 million for Bay Area and Central Valley charitable organizations. Livermore employees marked their sixth straight year of record-setting contributions. Through the HOME Campaign, the Laboratory is the largest single workplace supporter of the Tri-Valley Community Fund. The Community Fund is dedicated to raising and distributing local charitable contributions to human service, educational, cultural, and recreational organizations located throughout the Livermore, Amador, and San Ramon valleys in northern California.

Many outreach activities include employee participation in community assistance and economic development organizations. Brighter Holidays is a prime example of employee volunteerism and community outreach. The program, which started in 1989 by helping just a few local Livermore families, served 600 people from 137 families in nine counties in December 2003. The Holiday Card Fund and Toys for Children programs, sponsored by various Laboratory organizations, also help during the holiday season, as do Laboratory carpenters and quiltmakers who contribute handcrafts to charity.

In October 2003, Laboratory firefighters were on the front lines of wildfires that raged across southern California. The Laboratory dispatched two engines and two strike teams to provide assistance. As part of its mutual aid agreement to handle dispatch for Alameda County, the Laboratory sent a total of 21 engines and more than 70 firefighters from fire districts throughout the county.

Part of the University of California

Many mutually beneficial collaborations between the Laboratory and UC campuses serve to strengthen research programs at Livermore and provide the campuses access to Livermore's multidisciplinary capabilities and special research facilities. The Laboratory has especially strong ties with UC Davis dating from the

Laboratory employees generously support families in need with Brighter Holidays program.

Laboratory firefighters helped put out the southern California wildfires.

Director Michael Anastasio at the dedication of the Physical Biosciences Institute.

Laboratory and UC leaders dedicate the Edward Teller Education Center.

establishment of the Department of Applied Science campus at Livermore in 1965. Other major collaborations now include the Center for Biophotonic Science and Technologies (supported by the National Science Foundation) and the Integrated Cancer Center (designated a National Cancer Center by the National Cancer Institute). Both centers are housed at the UC Davis Medical Center in Sacramento. In September 2003, 40 UC Davis faculty and staff members visited the Laboratory to explore additional future collaborations. It was a full day of strategic planning, presentations by Laboratory researchers, and tours of facilities.

The Laboratory is also assisting in the establishment of UC Merced. The new university campus plans to have a close affiliation with Livermore, and its research will be aligned with the Laboratory's in a number of areas. Many additional research collaborations with UC campuses and other major universities are fostered by the Laboratory's six University Relations institutes. The newest, the Physical Biosciences Institute, opened its doors in March 2003 with seven postdoctoral fellows chosen from a large pool of applicants. The institute serves as an incubator for creating new research projects at the intersection of life sciences and other science and engineering disciplines.

Partners in Educational Outreach

As part of the University of California and as a national laboratory, Livermore has a long-standing commitment to enhancing education at all levels, including community college and K–12. Community educational outreach projects typically engage over 10,000 students and teachers annually. Programs such as Fun with Science (a traveling science show) and Science on Saturday (a series of lectures and demonstrations) raise scientific awareness and seek to influence students to consider college education.

One highlight of the Laboratory's many teacher-development programs is the Edward Teller Education Center's Teacher Research Academy. The Edward Teller Education Center (ETEC), which serves as a focal point for teacher-development activities at the Laboratory, was dedicated in September 2003. The center is sponsored by the Laboratory, the UC Office of the President, UC Davis, and UC Merced. ETEC's Teacher Research Academy was launched in 2003 with 80 participating teachers. Teachers receive instructional materials and equipment for use in their classrooms in scientific theme areas that align with work at the Laboratory.

Another event is the Edward Teller Science and Technology Symposium. This two-day professional development program is for secondary science education and community college faculty. Each year, up to 150 teachers from throughout California participate in hands-on workshops where they learn to use new teaching materials that are based on Laboratory research.

Livermore employees help local teachers develop computer skills.

Helping California Track Groundwater Contamination

Livermore works with the State of California on issues ranging from homeland security (see p. 16) to water management. With a suite of analytical tools at their disposal, Laboratory scientists are developing a comprehensive picture of California's groundwater resources. They are determining where contamination has occurred, what the groundwater flow pattern is, and where the groundwater originates. Livermore is partnering with the California State Water Resources Control Board and the U.S. Geological Survey on the state-mandated Groundwater Ambient Monitoring and Assessment (GAMA) Program to investigate the degree to which the state's groundwater is susceptible to contamination.

Since the program began in 1999, 1,200 of the approximately 16,000 public drinking wells scattered throughout the state have been tested. The work begins with age-dating the water because age is a good indicator of probability of contamination. Younger water has been in the aquifer for a shorter time, so it has more recent contact with ground surfaces where contaminants are present. To determine how long water has been out of contact with the atmosphere, Livermore scientists use a capability available only in a handful of laboratories worldwide to determine within a few years when younger water entered the aquifer. The direction and rate that the groundwater in the aquifer is flowing can be inferred from these age determinations.

The Del Valle Reservoir, near Livermore.

The data generated by the GAMA Program is maintained by the state in a geographic information system called GeoTracker. Developed by the Laboratory while an investigative team looked at leaking underground fuel tanks (LUFTs) and their effects on the state's groundwater, GeoTracker provides online access to data such as LUFT sites and all public well sites in California.

Award-Winning Science and Technology

Each year, the scientific and technological accomplishments of Livermore employees are recognized outside the Laboratory by prizes, awards, and front-page publicity. Some of these achievements are described here. In addition, Laboratory scientists and engineers were responsible for 164 invention disclosures, 109 U.S. patent applications, 37 first foreign patent applications, 67 issued U.S. patents, and 19 issued foreign patents in FY 2003.

Edward Teller was awarded the Presidential Medal of Freedom, the nation's highest civilian honor, by President George W. Bush. Bush lauded Teller's pivotal role in ending the Cold War and for being a strong advocate for national defense and the cause of human freedom.

Seymour Sack, a Livermore physicist, earned an Enrico Fermi Award in 2003 "for his contributions to the national security of the United States." The Fermi Award was presented by DOE Secretary Spencer Abraham on behalf of the President.

Larry Suter was granted the American Nuclear Society's Edward Teller Award. The society recognized him as one of the world's leading experts on laser hohlraum physics and honored him for seminal work on almost all aspects of laser hohlraum physics.

Livermore's Suter (left) received the Edward Teller Award with Hideaki Takabe of Japan's Institute for Laser Engineering.

Each year, *R&D Magazine* selects the 100 most technologically significant new products and processes, ones that are the most beneficial to the world at large. The Laboratory has received 97 R&D 100 Awards, including six winners in 2003:

The High-Average-Power, Electro-Optic Q Switch, a device that allows fast optical switching for high-average-power lasers used in machining, energy research, and national defense.

The Biological Aerosol Sentry and Information System (BASIS) for the early detection of biological pathogens. Livermore and Los Alamos national laboratories shared this award.

The Lasershot™ Precision Metal Forming System for shaping large-panel structural components, such as those used in the aviation industry.

The Ion-Beam, Thin-Film Planarization Process, which helped solve one of the greatest technical challenges for advancing extreme ultraviolet lithography (EUVL).

The EUVL Full-Field Step-and-Scan System for printing 50-nanometer features on computer chips, almost twice as small as features possible with other systems. This award was given jointly to researchers from Lawrence Livermore, Lawrence Berkeley, and Sandia national laboratories as well as Northrop Grumman Space Technology/Cutting Edge Optronics.

The MEMS-based adaptive optics phoropter, a technology that combines advances in astronomy and micromachining to enhance vision and improve early diagnosis and treatment of retinal diseases. Livermore shared this award with Sandia National Laboratories, the University of Rochester, Wavefront Sciences, Boston Micromachines Corporation, and Bausch & Lomb.

Six Laboratory physicists were named Fellows of the American Physical Society:

John Castor was recognized for work on radiatively driven stellar winds and contributions to the theory of opacities, equations of state, and radiation hydrodynamics.

Giulia Galli (photo at right) was cited for her important contributions to the field of ab initio molecular dynamics and to the understanding of amorphous and liquid semiconductors and quantum systems.

Steven Hatchett was cited for contributions to theory and experiments of implosion physics for inertial confinement fusion and for innovative designs for fast ignition.

Richard Klein was selected for work on computational astrophysics including star formation, radiatively driven stellar winds, instabilities in supernovae and magnetized neutron stars, and scaled laser experiments simulating strong shock phenomena in the interstellar medium.

Christian Mailhoit was recognized for his contributions to theoretical and computational condensed matter and materials physics, with emphasis on innovative discoveries related to quantum-confined semiconductor structures and high-pressure research.

Erich Ormond was selected for his work in nuclear structure physics, including both ab initio shell-model and Monte Carlo calculations and nuclear physics as applied to stockpile stewardship.

The American Society for Precision Engineering honored optical physicist Gary Sommargren with a Lifetime Achievement Award, recognizing his contributions to the science of precision optical metrology.

Former Laboratory Director Bruce Tarter was elected a Fellow of the American Association for the Advancement of Science for transforming the science base for post–Cold War national security and for sustained contributions to national science policy.

Ed Moses, project manager of the National Ignition Facility, was honored with an NNSA Award of Excellence for his “vision, planning, and leadership” and “extraordinary record of sustained accomplishments.”

Ed Moses (left) and Ambassador Linton Brooks, administrator of the National Nuclear Security Administration.

Siegfried Glenzer received the American Physical Society’s 2003 Award for Excellence in Plasma Physics Research. The award recognized his contributions to understanding plasma waves, atomic physics, and hydrodynamics of hot dense plasmas. Glenzer was the first scientist to conduct experiments inside the National Ignition Facility’s target chamber.

Jack Campbell was awarded the George W. Morey Award by the American Ceramics Society for his work and leadership in the development, characterization, and manufacturability of phosphate laser glass for high-peak-power lasers.

The Minerals, Metals & Materials Society named T. G. Nieh a Fellow of the society for his work on the superplasticity of metals and ceramics.

The American Society for Metals named John Elmer a Fellow in recognition of his innovative contributions to the development and application of synchrotron-based, in situ, spatially resolved x-ray diffraction techniques to the study of phase transformations during fusion welding.

Francois Heuze was elected vice president of the International Society for Rock Mechanics.

David Eaglesham was named vice president (president-elect) of the Materials Research Society.

Frank Robles received the Medalla de Oro from the Society of Mexican American Engineers for his efforts to increase the awareness of opportunities in science for minority youth and recruit students to work at the Laboratory. He was one of the three nation-wide recipients of the society's highest honor.

Two teams of scientists were awarded the 2003 Edward Teller Fellowships. Mike McCoy and Mark Seager were recognized for their work in developing some of the largest supercomputers in the world. Ben Santer and Ken Caldeira were cited for their work on modeling the effects of greenhouse gases on global climate change.

The Federal Laboratory Consortium for Technology Transfer granted the Extreme Ultraviolet Lithography (EUVL) project an Excellency in Technology Transfer Award for transferring to industry technology that will lead to more powerful microprocessors and memory chips with increased storage capacity. The EUVL team is made up of researchers from Lawrence Livermore, Lawrence Berkeley, and Sandia national laboratories.

The National Ignition Facility construction project won two national safety awards of excellence for its outstanding safety record. Jacobs Constructors, the NIF construction manager, received the prestigious Construction Industry Safety Excellence Award from the Construction Users Roundtable, an industry group dedicated to promoting cost-effective and safe construction methods. The National Safety Council honored NIF with its Perfect Year Award for the second year in a row.

The Environmental Protection Agency Region 9 honored the Laboratory and NNSA with two Champions of Green Government awards for pollution prevention projects: the Drain-Down Recovery Team for an approach to minimizing waste in drain and refill and the Photovoltaic (PV) Team for its work to promote PV use.

The U.S. Secretary of Health and Human Services honored Pedro Estacio and 23 other members of the Bioterrorism State and Local Preparedness Coordination Group with the Secretary's Award for Distinguished Service. Estacio serves as an adviser to the Secretary's Office of Public Health Emergency Preparedness.

A team of Laboratory scientists earned the Both Directions Award at the supercomputing conference SC2003 by winning the Bandwidth Challenge, a competition on the transfer of massive amounts of data.

Laboratory scientists Claire Max and Ellen Raber were two of nine inductees into the Alameda County Women's Hall of Fame in 2003 for their contributions in the fields of science and the environment, respectively.

Claire Max (left) and Ellen Raber.

HPCwire, the online magazine for high-performance computing in research laboratories, academia, and industry, named Ken Neves and Mark Seager to its list of Top People and Organizations to Watch in 2003.

Bob Shanilec of the Lawrence Livermore Television Network (LLTN) received the Crystal Award of Excellence from the Communicator Awards Video Competition while Donald Harrison, also of LLTN, earned an Award of Distinction from the same international competition. Shanilec also received an Aegis Award in a national competition for nonbroadcast organizations.

Bob Shanilec (left) and Donald Harrison.

Laboratory publications garnered three awards in the Society for Technical Communications International Competition.

The *Physics and Advanced Technologies 2001 Annual Report* (Gloria Cannon, Ralph Jacobs, and John Danielson) won a Distinguished Award.

Science & Technology Review magazine (Kim Budil, Louisa Cardoza, Arnie Heller, Amy Henke, Tom Isaacs, George Kitrinos, Kitty Madison, Ray Marazzi, Carolin Middleton, Ann Parker, Lew Reed, Katie Walter, Dean Wheatcraft, and Gloria Wilt) won an Excellence Award.

Serving the Nation for Fifty Years—Fifty Years of Accomplishments (Paul Chrzanowski, George Kitrinos, and Pam MacGregor) won an Excellence Award.

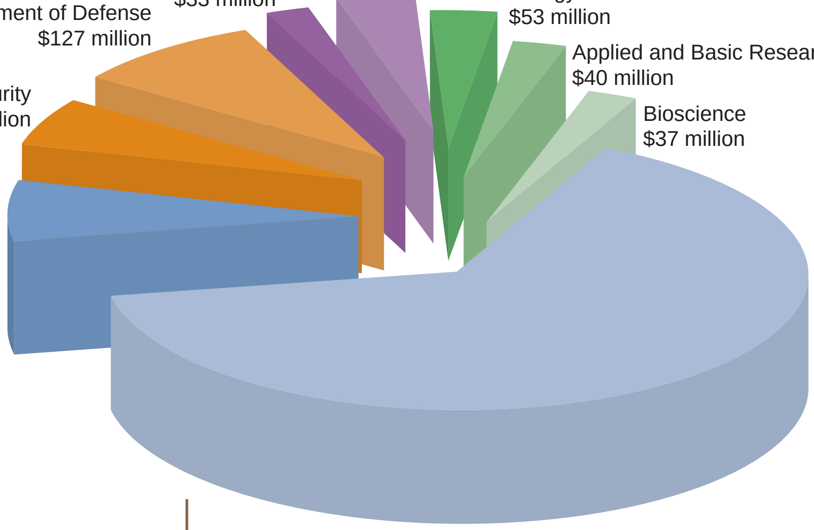
The *Science & Technology Review* team.

Laboratory Budget

Most of Livermore's $1.6-billion budget for FY 2003 was designated for research and development activities in program areas supporting the Department of Energy's missions.

As a national security laboratory, Livermore is part of DOE's National Nuclear Security Administration (NNSA). The Laboratory's funding largely comes from the NNSA Office of Defense Programs for stockpile stewardship activities. Support for national security and homeland security work also comes from the NNSA Office of Defense Nuclear Nonproliferation, the Department of Homeland Security, various Department of Defense sponsors, and other federal agencies.

As a multiprogram laboratory, Livermore applies its special capabilities to meet important national needs. Activities include work for other DOE programs, principally Environmental Management and the Offices of Science, Civilian Radioactive Waste Management, Nuclear Energy, and Security and Emergency Operations. Non-DOE sponsors include federal agencies (such as the National Aeronautics and Space Administration, Nuclear Regulatory Commission, National Institutes of Health, and Environmental Protection Agency), State of California agencies, and industry.

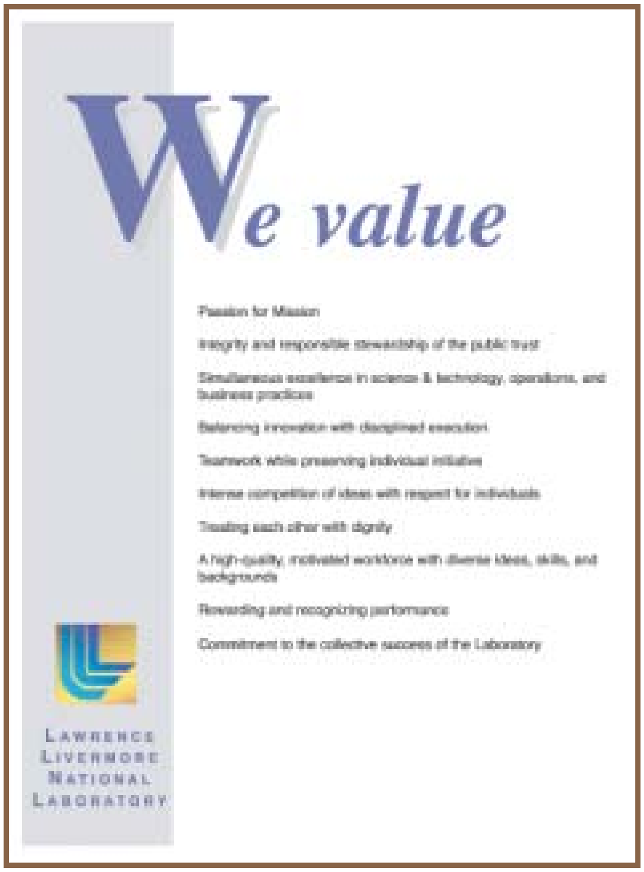


Laboratory Values

The Laboratory’s programmatic achievements and safe, secure, and efficient operations would not be possible without the dedicated efforts of all employees. Livermore seeks a highly talented, motivated staff that is committed to the Laboratory’s values and is reflective of the diversity of California and the nation. We strive for a work environment in which all employees can contribute to their fullest.

Find Out More about Us

Visit the Laboratory’s frequently updated Web site at http://www.llnl.gov/ to learn more about our many scientific and technical programs. Discover the many opportunities for employment, academic research, and industrial partnerships. Read about our accomplishments each month in *Science & Technology Review* in print or the Web at http://www.llnl.gov/str/.



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